ISSN 0377–9335

ENTOMON

Vol. 29 March 2004 No. 1

CONTENTS

Page

Why chemical ecology: emerging dimensions: T. N. Ananthakrishnan. 1

Effect of Carbon dioxide fumigation on the survival and tissue protein profile of the rice moth, *Corcyra cephalonica* (Stainton) (Lepidoptera: Galleriidae) : A. Premjith Jinham, S. Sam Manohar Das. 5

Influence of temperature on the survival, development of immature stages and reproduction of a ladybeetle, *Coccinella transversalis* Fabricius: Omkar, Barish E. James. 13

Scanning electronmicroscopic study of the cuticular structures on the head of *Gerris* sp. (Hemiptera: Gerridae) and *Cloeon* sp. (Ephemeroptera: Baetidae): S. Gupta, A. Gupta. 25

Mark-recapture studies for evidence of memorized site-fidelity in *Anopheles culicifacies* Giles, in Garhwal region: N. Pemola Devi, R. K. Jauhari. 31

A revised key to the world species of *Lisotrigona* moure (Hymenoptera : Apoidea : Apidae) with description of a new species from India: T. Jobiraj, T. C. Narendran. 39

Efficacy of new insecticides and neem formulations in the management of the citrus leaf miner, *Phyllocnistis citrella* Stainton (Phyllocnistidae: Lepidoptera): P. D. Kamala Jayanthi, Abraham Verghese. 45

Hitherto unknown Genus *Trigonobothrys* Simon (Theridiidae: Araneae) from India with description of the female of *Trigonobothrys martinae*: A. V. Sudhikumar, M. J. Mathew, P. A. Sebastian. 51

SHORT COMMUNICATIONS

Male accessory glands in Drosophila: a study on relationship between quantity of secretory proteins and body size: N. L. Lingegowda, S. R. Ramesh. 57

Host feeding pattern of *Coquillettidia (Coquillettidia) crassipes* (van der Wulp) from Kerala, India: P. Philip Samuel, N. Arunachalam, J. Hiriyan, V. Thenmozhi. . . 63

Host resistance in guava fruit fly *Bactrocera correcta* Bezzi management: S. Mohamed Jalaluddin, H. Usha Nandhini Devi, K. Natarajan. 67

Further studies on two Indian species of subgenus *Lutzia* Theobald of genus *Culex* Linnaeus (Diptera: Culicidae): J. S. Kirti, J. Kaur. 69

Continued on back cover

Department of Zoology, University of Kerala
Kariavattom, Trivandrum, India 695581

ENTOMON

ENTOMON is a quarterly journal of the Association for Advancement of Entomology issued in March, June, September and December, devoted to publication of research work on various aspects of insects and other arthropods.

EDITORIAL ADVISORY BOARD

T. N. ANANTHAKRISHNAN, Emeritus Scientist, Chennai
G. BHASKARAN, A & M University, Texas
K. P. GOPINATHAN, Indian Institute of Science, Bangalore
ZUO. R. SHEN, Agricultural University, Beijing

EDITORIAL BOARD

K. H. HOFFMANN, Germany
A. K. RAINA, Maryland
V. K. K. PRABHU, Trivandrum
N. MOHANDAS, Trivandrum
M. K. K. PILLAI, Delhi
K. S. S. NAIR, Trivandrum
R. GADAGKAR, Bangalore
T. C. NARENDRAN, Calicut
APARNA DUTTA GUPTA, Hyderabad
D. MURALEEDHARAN (Managing Editor)
MARIAMMA JACOB (Associate Editor)

Address MS and all editorial correspondence to Managing Editor, ENTOMON, Department of Zoology, University of Kerala, Kariavattom, Trivandrum 695581, India.

SUBSCRIPTION RATES

Annual subscription for Institutions: Rs. 1500.00 (in India); US$ 200 (Air Mail)
Annual subscription for individuals: Rs. 300.00 (in India); US$ 100 (Air Mail)

© 2004 by the Association for Advancement of Entomology. All rights reserved

1. All remittance to the Journal or Association should be sent to the Secretary-Treasurer of the Association by Bank Draft only, A/c payee in favour of the Association for Advancement of Entomology, payable at Kariavattom.
2. Requests for replacement copies of ENTOMON in lieu of numbers lost in transit, should reach the Secretary-Treasurer not later than three months after the date of publication of the number.

ENTOMON is covered in the following abstracting/indexing journals: *Chemical Abstracts, Review of Applied Entomology, Science Citation Index* and *Current Contents/Agriculture, Biology* and *Environmental Sciences, Biological Abstracts, Entomology Abstracts* and other relevant abstracts, *Referativny Zhurnal* and *Current Advance in Biological Sciences* and *New Entomological Taxa.*

Advances in Entomology – Opportunity to buy at reduced price

Limited copies of the publication **Advances in Entomology** are still available for sale. Based on the proceedings of Entomocongress 2000, this publication by AAE covers all aspects of Entomology and includes several state-of-the-science reviews on currently important topics, written by outstanding scientists from India and abroad. Refereed and carefully edited by an expert panel of editors for relevance and quality, this book will be a valuable addition to your personal library.

The AAE has taken a policy decision to offer the following concessions:

60% discount (discounted price Rs. 400)	-	to Postgraduate & Research students and Authors who contributed papers to the volume
40% discount (discounted price Rs. 600)	-	to book-sellers

AAE invites you to take advantage of this opportunity while copies last. Send the DD, drawn in favor of Secretary-Treasurer, AAE, payable at State Bank of Travancore, Kariavattom, addressed to Secretary-Treasurer, Association for Advancement of Entomology, Department of Zoology, University of Kerala, Kariavattom P.O., Trivandrum 695581.

ENTOMON **29(1)**: 1–3 (2004)
Article No. ent.29101

Why chemical ecology: emerging dimensions

T. N. Ananthakrishnan

Dwaraka 42, Kamdar Nagar, Nungambakkam, Chennai 600034, India

Over the years chemical ecology as a multidisciplinary field evinced varying interest among biologists around the globe, with increased involvement since the sixties and seventies, thanks to the sophisticated methods of isolation and identification of the concerned chemicals. With its increasing implications in applied research, notably in agriculture, horticulture and forestry following the development of useful interactions among chemists, biologists and ecologists serving to cement this discipline, the need for increased involvement in our universities, notably the agricultural universities, may not be asking for the impossible. This is all the more true in view of chemical ecology undergoing a major directional change—a direct consequence of its expansion with the contemporary field of molecular biology. It is the timely editorial in science by Eisner and Berenbaum (2002) entitled 'chemical ecology: missed opportunities', that prompted this brief write-up. According to them, 'the vocabulary of living things is overwhelmingly chemical in nature and partnerships between genomic biologists and chemical ecologists will likely be extremely synergistic. With only nanograms samples of messenger molecules being sufficient for an analysis, the ramification of this field has become enormous'. Having had occasion to initiate work in relation to chemical ecological aspects governing insect-plant interactions in the eighties, the feeling that much needs to be done in this area, cannot be ignored. To add further fillip to this need, the founding of the Max Planck Institute very recently for chemical ecology, further substantiates the growing recognition awarded to this discipline. While many laboratories in this country have been involved in some aspects of this field involving phytotoxins, mycotoxins, antibiotics and pharmaceutical aspects, in depth involvement in relation to changes in community composition including their cascading effects, as well as in relation to host plant resistance and interactions between insects and their natural enemies (Ananthakrishnan, 1999), are aspects deserving increased consideration.

It may not be out of place to mention that the foundations for chemical ecology as a science was laid by Lavoisier and Louis Pasteur and in a sense therefore, chemical ecology has been rediscovered, thanks to an understanding of allelopathic and allelochemic interactions, the principles of which are largely used in agriculture. In today's scenario several volatiles are known to affect insect communities resulting in behavioural diversities, such as that involving pheromones and host plant volatile (Ananthakrishnan, 1996). Recent trends also indicate attempts at integration of chemical ecology with biotechnology (Degenhardt *et al.*, 2003). Possibilities of

© 2004 Association for Advancement of Entomology

changing the metabolic pathways of plants to yield new metabolites which play an increasing role in resistance as well as attraction of natural enemies appear bright. The production of semiochemicals by plants as a bridging point in the biological production of semiochemical by molecular biological techniques is a vision for the future. Florkin (1966) in identifying the basic concepts of chemical ecology, indicated that, 'in the network of the biochemical continuum, a flow of molecules or of macromolecules which can carry a certain quality of information, is taking place'. Living organisms as such interact with their immediate environment by chemical molecules which are carriers of information. A host of such intra and interspecific interactions are known involving sex pheromones, social, alaram, defense pheromones, allomones and kairomones. Chemical ecology as such represents a turning point in evolution, illustrating a multitude of causal relationships.

Looking for another angle, in nature, a wide array of toxic substances exists, and a wide variety of ways have evolved in their usage. Phytotoxins, mycotoxins and antibiotics have been known for a long time and it has also gone on record that 'although the first observation of an antibiotic effect was made long ago, the isolation and identification of the first antibiotic was delayed partly because of the problem of coordinating efforts of biologists and chemists' (Barbier, 1976). It is in the area of chemical defenses of arthropods that considerable work has been done over the last three decades, on spider, ant, wasp and centipede venoms (Barbier, 1976) besides several plant toxins affecting caterpillars such as cardiac and cyanogenic glycosides, so that chemical weaponry has become an inseparable part of chemical ecology. The increasing host range of several insects has resulted from their overcoming the diverse metabolic pathways, thanks to the array of enzymes. Besides activating the plants' own natural defenses to prevent crop diseases and enhancement of several enzymatic activities contributing to resistance are well known. Spectacular applications are also now known in the pharmacology of marine life (Barbier, 1976), so that the scope of investigations in the field of chemical ecology is boundless and remains an enigma! Besides the need to understand such multi-impact studies as the combined effects of climatic factory, CO_2, drought, temperature, plant nutrition, will enable prediction of how herbivorous insects respond to environmental changes. Variations in susceptibility to insect attack have necessarily to be related to the proportion of various terpenoids between host species, between populations and within individual trees, so as to enable a better understanding of polymorphs, chemotypes or biotypes and even chemical races (Harrington and Stork, 1995). In short 'Nature still remains a gigantic catalogue of models and knowledge of such models relies on the close collaboration between biologists and chemists' (Scheur, 1973).

REFERENCES

Ananthakrishnan, T. N. (1996) Molecular messengers in insect biocommunication: Modality and relevance in biological control. *Curr. Sci.* **70**: 215–218.

Ananthakrishnan, T. N. (1999) Behavioral dynamics in the biological control of insects: Role of infochemicals. *Curr. Sci.* **77**: 33–37.

Barbier, M. (1976) *Introduction to Chemical Ecology*, Longman: London, p. 128.

Degenhardt, J., Gershenzon, J., Baldwin, I. T. and Kessler, A. (2003) *Current Opinion in Biotechnology* **14**: 69–476.

Eisner, T. and Berenbaum, M. (2002) Chemical Ecology: Missed opportunities? *Science* **295**: 1973.

Florkin, M. (1966) *Aspects moleculaires de l' adaptations et de la phylogenie*, Masson: Paris, p. 128.

Harrington, R. and Stork, N. E. (1995) *Insects in a Changing Environment*, Royal Ent. Soc., Academic Press: p. 535.

Scheur, P. (1973) *Chemistry of Marine Natural Products*, Academy Press: London, pp 201.

ENTOMON **29(1)**: 5–11 (2004)
Article No. ent.29102

Effect of Carbon dioxide fumigation on the survival and tissue protein profile of the rice moth, *Corcyra cephalonica* (Stainton) (Lepidoptera: Galleriidae)

A. Premjith Jinham and S. Sam Manohar Das*

Department of Zoology, Scott Christian College, Nagercoil 629003, India

ABSTRACT: First to fifth instar larvae of *Corcyra cephalonica* were fumigated with CO_2 for durations of 10, 20, 30 and 45 min. Fifth instar larvae which received a first dose of fumigation for 30 min, were given an additional, second dose of fumigation for varying durations, at 60, 120 and 180 min interval after the first fumigation. Fumigated first instar larvae blacked out quickly and revived slowly compared to the older instars. Upon revival, the fourth and fifth instar larvae spun silken cocoons faster than the first instar. There were significant changes in the tissue protein profile of the larvae exposed to the two different fumigation schedules.
© 2004 Association for Advancement of Entomology

KEYWORDS: *Corcyra cephalonica*, CO_2 fumigation, tissue protein profile

INTRODUCTION

Management of *Corcyra cephalonica* (Stainton) (Lepidoptera: Galleriidae) with gamma radiation (Khattak and Jilani, 1985 and Baky and Hasaballa, 1991), microwaves (Locatelli and Traversa, 1989) and UV radiation (Singh *et al.*, 1994) had been well documented. Fumigation with phosphine, methyl bromide, ethylene dibromide and ethyl formate and carbonyl sulphide had already been tried with considerable success (Highland *et al.*, 1984; Rao *et al.*, 1991; Bowry, 1985 and Zettler *et al.*, 1997). Fumigation with carbon dioxide is a common method for control of stored grain pests (Suss *et al.*, 1991 and White and Jayas, 1993). In the present study the effects of CO_2 fumigation on different larval instars of the rice moth, *C. cephalonica* and changes in the tissue protein profile of the insects, consequent to fumigation were assessed.

*Corresponding author

© 2004 Association for Advancement of Entomology

MATERIALS AND METHODS

C. cephalonica caterpillars were obtained from the Entomological Research Station, St. Xaviers College, Palayamkottai and maintained in the laboratory to obtain a fresh population of adult moth. The mated females were separately maintained in wire netted cages and eggs produced were collected, incubated and upon hatching reared on wheat flour and different instars segregated. Each instar was subjected to CO_2 fumigation exactly 24 h after moulting.

First dose

The fumigation chamber consisted of three 1 litre conical flasks fitted with two holed rubber stoppers. Long glass tubes were introduced into these holes, one of which served as the inlet while the other as the outlet. A 25 kg commercial CO_2 cylinder was connected to the first conical flask through a specially designed valve system and the conical flasks were serially connected. The final outlet was connected to rubber tubing that dipped in water to prevent the entry of atmospheric air into the flasks and to reduce the amount of CO_2 pumped out into the atmosphere. About 10 worms belonging to a particular instar were introduced in to each flask and subsequently fumigated for known time intervals.

Second dose

This consisted of two consecutive fumigation sessions of varying durations with different time intervals in between fumigations.

Worms fumigated for designated periods were removed from the exposure system and kept in atmospheric air for revival. Time taken for complete revival was recorded. Spinning activity was absent during the exposure and it regained upon revival. Time taken for construction of a complete web (cocoon) was recorded. Blackout was regarded as the point at which the worms became unconscious. Body movements came to a standstill, most worms lost foothold and sprawled laterally.

Electrophoretic studies

Electrophorogram of tissue proteins of fifth instar *C. cephalonica* was analysed through SDS PAGE of control, 45 min CO_2 single fumigation and double fumigation, with two sessions of 30 min each with an interval of 180 min.

The treated larvae were pooled in lots of 10 mg, washed with double distilled water and then with insect Ringer solution to remove the debris. Larvae were crushed in a glass homogeniser with Teflon pestle in 150 μl of homogenizing buffer (Tris-EDTA, pH 6.8) Homogenization was done in an ice-bath under freezing conditions. Every sample was homogenized separately. Homogenised samples were centrifuged at 12000 rpm for 15 min at 4 °C in a refrigerated centrifuge. Supernatant was taken out and mixed with equal volume of sample buffer and stored at −4 °C in a deep freeze.

Equal volumes of sample buffer containing 0.15 M Tris-HCl- pH 6.8, 10% SDS glycerol, β-mercaptoethanol and traces of bromophenol blue were added to the

TABLE 1. Effect of CO_2 fumigation on *C. cephalonica*

Instar	Duration of fumigation (min)	Black-out time (sec)	Revival time (sec)	Spinning time (sec)
I	10	152 ± 8	389 ± 26	707 ± 35
	20	93 ± 12	471 ± 38	712 ± 65
	30	47 ± 8	601 ± 50	74 ± 22
	45	44 ± 8	312 ± 21	51 ± 15
II	10	222 ± 38	232 ± 29	550 ± 38
	20	140 ± 21	322 ± 34	620 ± 38
	30	108± 15	199 ± 19	220 ± 30
	45	90 ± 14	165 ± 17	111 ± 17
III	10	303 ± 32	241 ± 37	465 ± 34
	20	194 ± 22	297 ± 42	553 ± 47
	30	157 ± 27	125 ± 29	208 ± 41
	45	110 ± 24	137 ± 27	123 ± 26
IV	10	308 ± 40	173 ± 48	393 ± 35
	20	195 ± 19	220 ± 23	423 ± 39
	30	198 ± 22	120 ± 28	195 ± 50
	45	155 ± 30	164 ± 46	205 ± 61
V	10	387 ± 25	147 ± 17	423 ± 23
	20	216 ± 33	135 ± 24	315 ± 35
	30	207 ± 21	87 ± 10	142 ± 17
	45	155 ± 21	97 ± 9	130 ± 18

supernatant samples, boiled for 2 min and kept on ice immediately to prevent denaturation by overheating. Samples were again centrifuged at 8000 rpm for 5 min at 4 °C before loading into the well in the precasted gel.

Protein concentration of whole tissue was determined following the method of Lowry *et al.* (1951). Bovine serum albumin served as the standard protein. Protein determination was done to standardize the amount of tissue to be used for the preparation of samples for electrophoretic studies.

SDS-PAGE (Sodium dodecyl sulphate polyacrylamide gel electrophoresis) was carried out following the method of Laemmli (1970) using 8% separating and 5% stacking slab gels. Each well was loaded with 50 μl sample. A constant current of 60 volts for stacking and 120 volts for running gel were used for 3 h. Gels were stained overnight in Coomassie brilliant blue R 250. After the run, gels were destained, stored in 7% acetic acid, photographed and subsequently documented in a computerized gel documentation unit to calculate the RF values and obtain the different densitometric peaks.

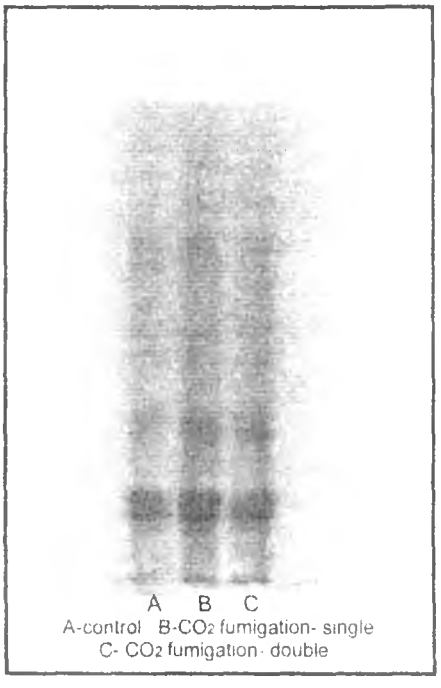


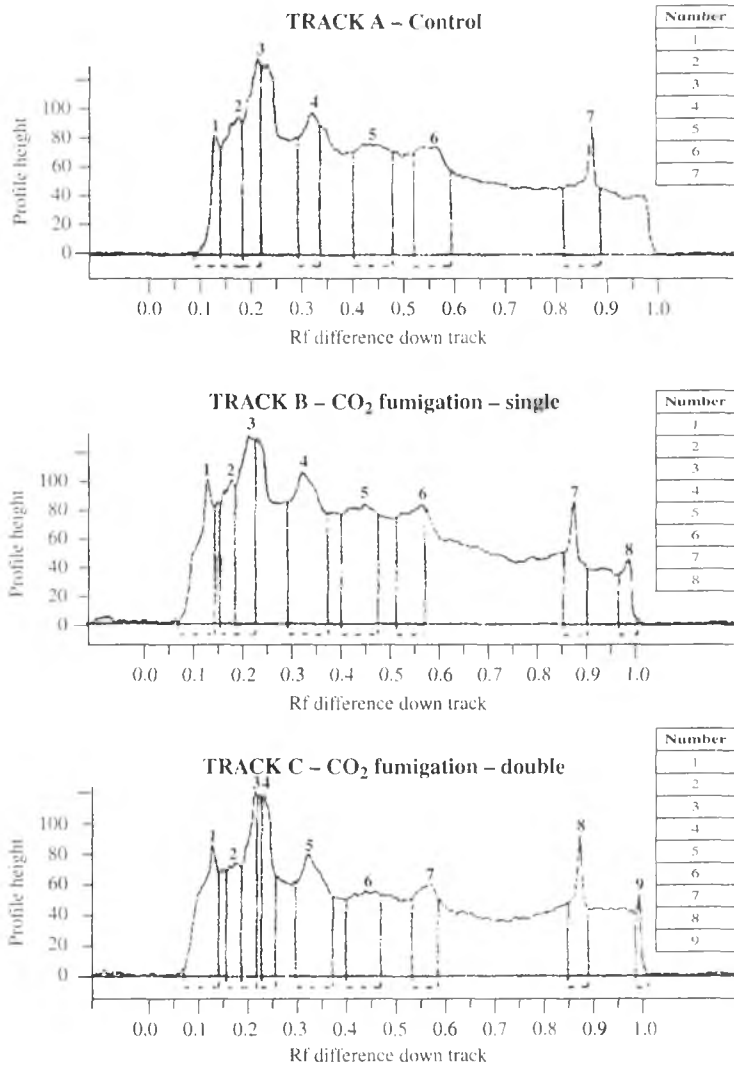
FIGURE 1. Electrophoretic pattern

RESULTS AND DISCUSSION

Black-out time was highest in fifth instar in fumigation for 10 min (387 sec), and the lowest (44 sec) in first instar in fumigation for 45 min (Table 1). Older instars resisted fumigation, while younger instars were more susceptible. Revival was comparatively slower in younger instars while it was much quicker in older instars. First instar larvae took longer time for spinning while the fifth instar took the least. In fumigation for more than 30 min, spinning was erratic and incomplete with formation of flimsy cocoons and the spinning time was considerably less.

When fumigation was given in two sessions to fifth instar larvae, highest eclosion rate (83.3%) was observed, when the second fumigation for 10 min was given after one hour interval (Table 2). Eclosion was lowest (16.7%) when there were two fumigations of 30 min sessions with an interval of three hours. It was evident that in double fumigations, the first fumigation seemingly brought about certain deleterious physiological changes, which become fixed during the long interval, so that the second fumigation became highly effective.

The electrophoretic pattern (Fig. 1) showed the presence of seven protein peaks with RF values ranging from 0.129 to 0.871 in the control worms. The number of peaks increased to 8 with RF values ranging from 0.1265 and 0.9878 in single fumigation



Number	Rf	% Raw Vol.
1	0.1290	5.838
2	0.1752	13.255
3	0.2117	14.698
4	0.3212	13.863
5	0.4331	20.352
6	0.5645	18.106
7	0.8710	13.886

Number	Rf	% Raw Vol.
1	0.1265	11.395
2	0.1776	8.821
3	0.2141	14.548
4	0.3212	22.569
5	0.4477	17.885
6	0.5645	13.663
7	0.8735	7.717
8	0.9878	3.402

Number	Rf	% Raw Vol.
1	0.1290	13.559
2	0.1727	8.574
3	0.2117	11.374
4	0.2311	10.707
5	0.3236	18.966
6	0.4574	14.138
7	0.5718	11.324
8	0.8735	9.155
9	0.9951	2.204

FIGURE 2. Densitometric scanning of the electrophorogram

of fifth instar for 45 min, while in double fumigation each of 30 min duration, with three hours interval, there were 9 protein peaks with RF values ranging from 0.1265 to 0.9951 (Fig. 2). Only one protein found in the control remained unchanged in single fumigation with a RF of 0.3212, eventhough there is a notable change in the raw volume. Two proteins were similar in the two fumigation modes, with RF values of 0.1265 and 0.8735, with small changes in the raw volume. This indicated a similarity in the response of the worms to the two different types of fumigation. Sundaramurthy

TABLE 2. Effect of second * fumigation with CO_2 on eclosion rate of 5th instar *C. cephalonica*

Interval after first dose (min)	Duration of second dose (min)	Eclosion %
	10	83.3
60	20	66.7
	30	50.0
	10	50.0
120	20	33.3
	30	33.3
	10	33.3
180	20	33.3
	30	16.7

* All the larvae were given a first dose of fumigation for 30 min.

and Ahmed (1978); Kajiura and Yamashita (1989) and Sohal and Rup (1998) showed that chemical stress produced significant changes in the tissue protein content, with increase in the number of protein bands and their relative mobility, indicating synthesis of new proteins to combat stress.

ACKNOWLEDGEMENTS

We are thankful to Dr. S. Prasanna Kumar, HOD of Zoology and Dr. A. D. Sobhana Raj, Principal, Scott Christian College, Nagercoil for the facilities provided and Dr. Dunston P. Ambrose, Director, Entomological Research Unit, St. Xaviers College, Palayamkottai for supplying *C. cephalonica* samples. We are grateful to Dr. Prakash Vincent, Lecturer, Institute for coastal area studies, Rajakkamangalam for his help in documenting the gels.

REFERENCES

Baky, A. S. M. and Hasaballa, Z.A. (1991) Biological and chemical studies on the irradiated rice meal moth, *Corcyra cephalonica* (Staint). *Assuit Journal of Agricultural Sciences* **22(1)**: 203–212.

Bowry, S.K. (1985) A note of the effective dosage of some fumigants against certain stages of *Corcyra cephalonica* (Staint). *II. East African Agricultural and forestry Journal* **51(2)**: 116–118.

Davis, R.E., Kelly, T.J., Kasler, E.P., Fescemyer, H.W., Thyagaraja, B.S. and Borkovee, A.B. (1990) Hormonal control of vitellogenesis in the gypsy moth *Lymantria dispar*(L.). *J. Insect Physiol.* **36**: 231–238.

Highland, H.A., Leesch, J.G., Cline, L.D. and Zehner, J.M. (1984) Phosphine fumigation of thick film polyethene food bags and laminated film food packets. *Journal of Economic Entomology* **77(4)**: 1041–1045.

Kajiura, Z. and Yamashita, O. (1989) Stimulated synthesis of the female specific storage protein in the male larvae of the silkworm *Bombyx mori* treated with juvenile hormone analog. *Arch. Insect. Biochem. Physiol.* **12**: 99–109.

Khattak, S.U.K. and Jilani, G (1985) Interaction of gamma radiation and vacuum for the control of four beetles. *Pakistan Journal of Agricultural research* **6(1)**: 45–48.

Laemmli, U.K. (1970) Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature* **227**: 680–685.

Locatelli, D.P. and Traversa, S (1989) Microwaves in the control of rice infestants. *Italian Journal of Food Science* **1(2)**: 53–62.

Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J. (1951) Protein measurement with the folin phenol reagent. *J. Biol. Chrm* **193**: 265–275.

Rao, G.V.R., Surender, U.R.A., Murthy, K.S. and Joshi, N.C. (1991) Effect of phosphine and methyl bromide fumigation on eggs and larvae of rice moth *Corcyra cephalonica S.* a common stored grain pest. *Indian Journal of Plant Protection* **19(1)**: 89–91.

Singh, S., Paul, A.V.N. and Bharti, D (1994) Effect of UV radiation on mortality of *Corcyra cephalonica* Stainton(Lepidoptera:Galleriidae) and *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) eggs. *Indian Journal of Entomology* **56(4)**: 347–351.

Sohal, S.K. and Rup, P.J. (1998) Electrophoretic and quantitative changes in the protein content of *Lipaphis erysimi* (Kalt) under the influence of methoprene treatment. *Entomon* **23(1)**: 11–15.

Sundaramurthy, V.T. and Ahmed, N.M. (1978) Effect of altosid on the blood protein of caterpillar of *Spodoptera litura* Fb. (Noctuidae: Lepidoptera). *Curr. Sci.* **47**: 170–171.

Suss, L., Locatelli, D.P. and Frati, M. (1991) The use of carbon dioxide in cereal pest control. *Tecnica- Molitoria* **42(4)**: 333–338.

White, N.D.G. and Jayas, D.S. (1993) Effectiveness of carbon dioxide in compressed gas or solid formulation for the control of insects and mites in stored wheat and barley. *Phytoprotection* **74(2)**: 101–111.

Zettler, J.L., Leesch, J.G., Gill, R.F. and Mackey, B.E. (1997) Toxicity of carbonyl sulfide to stored product insects. *J. Econ. Entomol.* **90(3)**: 832–836.

(Received 24 February 2003; accepted 12 August 2003)

ENTOMON **29(1):** 13–23 (2004)
Article No. ent.29103

Influence of temperature on the survival, development of immature stages and reproduction of a ladybeetle, *Coccinella transversalis* Fabricius

Omkar* **and Barish E. James**

Department of Zoology, University of Lucknow, Lucknow 226007, India
Email: omkaar55@hotmail.com

ABSTRACT: The immature survival, pre-imaginal development and reproductive potential of a ladybeetle, *Coccinella transversalis* Fabricius, were investigated at 20, 25, 27, 30 and 35 °C temperature, using aphid, *Aphis gossypii* Glover as a prey. Rate of development increased with increase in temperature from 20 to 35 °C. The theoretical lower thermal threshold for development and the thermal constant was 9.04 °C and 245.10 day-degrees, respectively. The pre-imaginal development was lowest at 20 °C and highest at 35 °C. The per cent larval survival, adult emergence and growth index also increased with increase in temperature from 20 to 27 °C and thereafter decreased upto 35 °C. Maximum fecundity and percent viability of eggs was recorded at 27 °C and minimum at 35 °C. Thus, 27 °C was the optimum temperature for the survival, development of immature stages and reproduction of *C. transversalis*. © 2004 Association for Advancement of Entomology

KEYWORDS: *Coccinella transversalis*, temperature, survival, development, reproduction, fecundity

INTRODUCTION

Coccinella transversalis Fabricius is a predaceous ladybeetle native to India and abundant in South Asia (Omkar and Pervez, 2000). It is commonly found predating on the aphids, *Aphis craccivora* Koch, *Aphis gossypii* Glover and *Lipaphis erysimi* (Kalt.) in agricultural and horticultural fields (Omkar and Bind, 1993) and is one of the important members of the local predator complex. Recent studies on its predatory potential and prey-predator interactions revealed its effectiveness as an important biocontrol agent for certain aphid pests (Agarwala and Bardhanroy, 1999; Babu, 1999; Joshi *et al.*, 1999; Debraj and Singh, 2000; George, 2000; Evans, 2000; Omkar and James, 2001; James, 2001).

Temperature is a crucial factor, which influences the bio-attributes of predaceous coccinellids (Ponsonby and Copland, 1996, 1998); being a major determinant in the survival and development of immature stages and and reproductive performance

*Corresponding author

© 2004 Association for Advancement of Entomology

(Ponsonby and Copland, 1996, 1998; Jalali *et al.*, 1999; Omkar and Pervez, 2002). The studies on the effects of temperature may contribute to effective mass-rearing and provide a quantitative basis for predicting development, seasonal growth and predatory activity of ladybeetles (Veeravel and Baskaran, 1996). Such studies may also provide some evidence to aid the evaluation of relative competitiveness and adaptability of ladybeetles to local temperatures (Frazer and McGregor, 1992). The lack of information on the influence of temperature on the survival, development and reproduction of *C. transversalis* prompted us to undertake this study.

MATERIALS AND METHODS

Laboratory maintenance

The larvae and adults of *C. transversalis* were collected from agricultural fields adjoining the city of Lucknow, India, and brought to the laboratory where the stock culture was maintained at 27 ± 1 °C and $65 \pm 5\%$ R.H. Mating pairs were kept in glass beakers (11 cm height and 7 cm diameter) covered with fine muslin cloths fastened with rubber bands. The ladybeetles were fed on *A. gossypii* infested on bottle gourd (*Lagenaria vulgaris*) twigs. The left over aphids and dried twigs were replaced daily with fresh ones to avoid contamination. The eggs were collected daily.

Effect of temperature on the survival and development of immature stages

Five sets of one hundred eggs were taken out from the stock and kept in separate Petri dishes at five different temperatures *viz.*, 20, 25, 27, 30 and 35 °C and controlled humidity (65% R.H.). After hatching, the incubation period and number of first instars were recorded. These were transferred from Petri dishes to glass beakers (diameter 6.5 cm × height 9.5 cm) and reared on *A. gossypii*. Sufficient quantity of aphids was given to minimize the occurrence of cannibalism. The leftover aphids and dried host plant twigs were replaced by fresh ones regularly every twenty-four hours to avoid contamination and the consequent mortality. Thereafter, the number of larvae surviving after each moult and the duration of each instar were recorded. The number of pupae and the pupal period were recorded prior to the emergence of adults. The experiment was replicated ten times. The data were subjected to analysis of variance (ANOVA) and regression analysis using a statistical package "Statistix 4.1". The comparison of means was carried out using Bonferroni's method. The developmental rate (1/developmental period), larval survival (Number of pupae formed $\times 100$/ Number of first instar larvae hatched), adult emergence (Number of adult beetle emerged $\times 100$/ Number of pupae formed) and growth index (Per cent pupation/Mean larval duration) of the ladybeetle were calculated. Developmental rate was fitted with temperature to obtain the relationship in terms of $1/D = aT + b$ where, D = developmental period, T = temperature, and a and b are regression parameters fitted to the observed data. Thereafter, lower thermal threshold for development ($-b/a$) and the thermal constant ($1/a$) were calculated.

Effect of temperature of reproduction

Five pairs of newly emerged ladybeetles were selected from the laboratory stock and kept in glass beakers (diameter 6.5 cm × height 9.5 cm) along with twigs infested with *A. gossypii*. The open ends were covered with fine muslin cloths fastened with rubber bands. These were kept in Environmental Test Chambers at five different temperatures, i.e. 20, 25, 27, 30, and 35 °C for their lifetime. Dried twigs containing leftover aphids were replaced daily with fresh twigs having a sufficient infestation of *A. gossypii*. The eggs laid by the female were counted and separated daily from adults to prevent them from cannibalism. The fecundity and egg viability at different temperatures were recorded in ten replicates and the data were subjected to analysis of variance and comparison of means was carried out using Bonferroni's method following a statistical package "Statistix-4.1". The fecundity was correlated with temperature by single polynomial regression analysis and a best fit line was drawn ($n = 10$).

RESULTS

Effect of temperature on the survival and development of immature stages

The incubation period ($F = 108.47$; $P < 0.001$) and the durations of first ($F = 20.00$; $P < 0.001$), second ($F = 30.59$; $P < 0.001$), third ($F = 31.30$; $P < 0.001$) and fourth ($F = 39.65$; $P < 0.001$) instars decreased significantly with the increase in temperature from 20 to 35 °C (Table 1). The total larval ($F = 51.76$; $P < 0.001$), prepupal ($F = 107.29$; $P < 0.001$) and pupal ($F = 47.93$; $P < 0.001$) periods decreased significantly with increase in temperature from 20 to 35 °C. The total pupal period also decreased significantly ($F = 110.92$; $P < 0.001$). The complete development period decreased significantly from 21.56±2.18 to 10.69±1.08 days ($F = 124.37$; $P < 0.001$). Figure 1 exhibits a linear relationship between developmental rate and temperature. The regression equation was $Y = -0.0369 + 0.00408X$ ($r^2 = 0.99$; $P < 0.001$). From this equation the theoretical lower threshold for development was found to be 9.04 °C and the thermal constant was 245.10 day-degrees. The regression equations in Table 2 show a negative equation for the durations of various developmental stages with increase in temperature. Table 3 reveals that the ratio of time spent in each instar in relation to total larval period was nearly same at each temperature regime. Duration of fourth instar was longest and second instar was shortest amongst different instars of *C. transversalis* and duration of prepupa was shortest amongst all life-stages (Fig. 2).

The per cent larval survival varied from 32.20 ± 1.51 to 60.30 ± 1.93 ($F = 23.38$; $P < 0.001$) with increase in temperature from 20 to 35 °C. It was maximum at 27 °C and minimum at 20 °C temperature (Table 4). The first instar larva suffered the highest percent mortality, whilst pupa the lowest. The percent adult emergence varied from 42.08 ± 3.56 to 87.14 ± 1.91 ($F = 55.27$; $P < 0.001$) with the increase in temperature from 20 to 35 °C and was highest (87.14%) at 27 °C and lowest (42.08%) at 35 °C temperature. The growth index of the ladybeetle varied from 2.06 ± 0.11 to

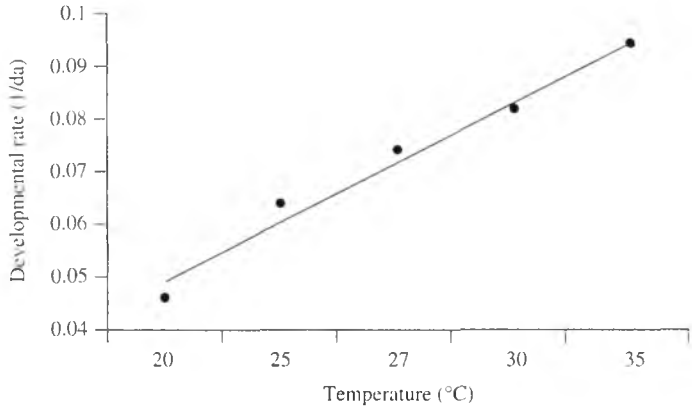


FIGURE 1. Best fit line for predicting the development of the immature predator stages of *C. transversalis* at different temperatures, using *A. gossypii* as prey ($n = 10$).

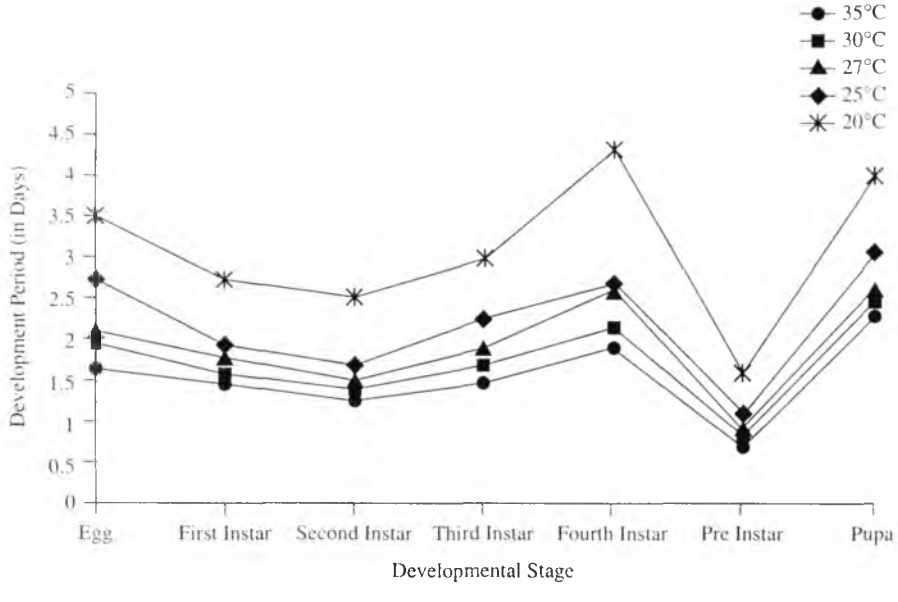


FIGURE 2. Developmental period of various life stages of *C. transversalis* at different constant temperatures.

6.98 ± 0.38 ($F = 29.70$; $P < 0.001$) with increase in temperature from 20 to 35 °C. It was highest at 27 °C and lowest at 20 °C.

TABLE 1. Duration of development (in days) of different immature stages of *C. transversalis* at different temperatures

Temp. (°C)	Incubation period	First instar	Second instar	Third instar	Fourth instar	Total larval period	Prepupal period	Pupal period	Total pupal period	Complete development
20	3.48 ± 0.35*a*	2.71 ± 0.27*a*	2.50 ± 0.25*a*	2.95 ± 0.30*a*	4.32 ± 0.44*a*	12.48 ± 0.24*a*	1.59 ± 0.16*a*	4.01 ± 0.41*a*	5.60 ± 0.51*a*	21.56 ± 2.18*a*
25	2.69 ± 0.27*b*	1.92 ± 0.19*b*	1.67 ± 0.17*b*	2.25 ± 0.23*b*	2.68 ± 0.29*b*	8.70 ± 0.88*ba*	1.10 ± 0.11*b*	3.07 ± 0.31*b*	4.16 ± 0.42*b*	15.56 ± 1.58*b*
27	2.08 ± 0.21*c*	1.76 ± 0.18*bc*	1.51 ± 0.15*bc*	1.91 ± 0.19*bc*	2.61 ± 0.26*bc*	7.79 ± 0.79*bc*	0.93 ± 0.09*c*	2.67 ± 0.27*bc*	3.60 ± 0.37*c*	13.48 ± 1.36*c*
30	1.93 ± 0.20*c*	1.57 ± 0.16*bc*	1.41 ± 0.14*bc*	1.69 ± 0.17*cd*	2.18 ± 0.22*cd*	6.85 ± 0.69*cd*	0.83 ± 0.08*c*	2.51 ± 0.25*c*	3.34 ± 0.34*cd*	12.16 ± 1.23*cd*
35	1.63 ± 0.17*d*	1.45 ± 0.15*c*	1.26 ± 0.13*c*	1.47 ± 0.15*d*	1.91 ± 0.19*d*	6.08 ± 0.62*d*	0.68 ± 0.07*d*	2.30 ± 0.23*c*	2.98 ± 0.30*a*	10.69 ± 1.08*d*
F-values	108.47*	20.00*	30.59*	31.30*	39.65*	51.76*	107.29*	47.93*	110.92*	124.37*

Values are Mean ± SE; *Significant at $P < 0.001$; Differences are denoted by the letters *a*, *b*, *c* and *d*;
Same letter in the column denotes that data are not significantly different.

TABLE 2. Regression equations at different durations predicting development of various life immature stages of *C. transversalis* at different temperatures

Duration of development	r^2	Regressions equations
Incubation	0.8355	$Y = 3.704 - 0.447X$
First instar	0.5363	$Y = 2.741 - 0.287X$
Second instar	0.5791	$Y = 2.496 - 0.275X$
Third instar	0.6831	$Y = 3.109 - 0.352X$
Fourth instar	0.6683	$Y = 4.428 - 0.551X$
Total larval period	0.7085	$Y = 12.772 - 1.465X$
Prepupa	0.8037	$Y = 1.653 - 0.209X$
Pupal	0.7032	$Y = 4.108 - 0.398X$
Total pupal period	0.7951	$Y = 5.754 - 0.606X$
Total development period	0.8073	$Y = 22.231 - 2.518X$

TABLE 3. Ratio of time spent in each instar of *C. transversalis* in relation to total larval period at different temperatures

Temperature	Ratio of first, second, third and fourth instar periods to the total larval period
20 °C	0.22 : 0.20 : 0.24 : 0.34 : 1
25 °C	0.23 : 0.20 : 0.26 : 0.31 : 1
27 °C	0.23 : 0.19 : 0.25 : 0.33 : 1
30 °C	0.23 : 0.21 : 0.25 : 0.31 : 1
35 °C	0.24 : 0.21 : 0.24 : 0.31 : 1

TABLE 4. Larval survival, adult emergence, growth index, fecundity and egg viability of *C. transversalis* at different temperatures

Temp. (°C)	Larval survival (%)	Adult emergence (%)	Growth index	Fecundity (eggs)	Egg viability (%)
20	32.20 ± 1.51*a*	45.86 ± 2.60*a*	2.06 ± 0.11*a*	370.60 ± 13.68*e*	79.89 ± 0.83*ab*
25	46.30 ± 1.18*b*	71.37 ± 1.89*b*	4.40 ± 0.30*b*	810.30 ± 33.09*c*	82.83 ± 0.90*bc*
27	60.30 ± 1.93*c*	87.14 ± 1.91*c*	6.98 ± 0.38*d*	1319.80 ± 20.71*a*	90.06 ± 1.30*d*
30	47.60 ± 1.76*b*	73.76 ± 2.49*b*	5.95 ± 0.34*cd*	1037.90 ± 12.28*b*	85.55 ± 1.17*dc*
35	39.30 ± 3.48*ab*	42.08 ± 3.56*a*	4.93 ± 0.47*bc*	537.90 ± 9.45*d*	76.37 ± 1.55*a*
F-value	23.38*	55.27*	29.70*	375.28*	19.99*

Values are Mean ± SE; *Significant at $P < 0.001$; Differences are denoted by the letters *a*, *b*, *c*, *d* and *e*; Same letter in the column denotes that data are not significantly different.

Effect of temperature on reproduction

The fecundity of the ladybeetle increased significantly from 370.60 ± 13.68 to 1319.80 ± 20.71 eggs ($F = 375.28$; $P < 0.001$) with increase in temperature from 20

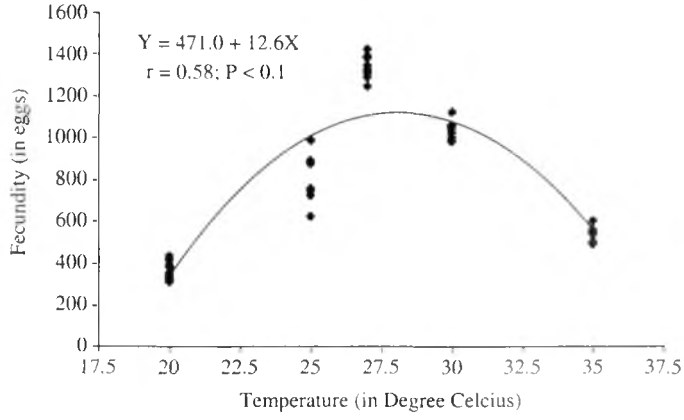


FIGURE 3. Best fit line showing a positive corelation between the fecundity of *C. transversalis* and the increase in temperature ($n = 10$).

to 27 °C and decreased upto 537.90 ± 9.54 eggs on further increased in temperature to 35 °C (Table 3). The percent viability of eggs increased from 79.89 ± 0.83 to 90.06 ± 1.30 ($F = 19.99$; $P < 0.001$) with increase in temperature from 20 to 27 °C and decreased to 76.37 ± 1.55 on further increase in temperature up to 35 °C. The single polynomial regression analysis of fecundity of ladybeetle at different temperatures yielded the regression equation $Y = 471.0 + 12.6X$; $r = 0.58$; $P < 0.01$ (Fig. 3).

DISCUSSION

Effect of temperature on the survival and development of immature stages

The results revealed that the pre-imaginal period of *C. transversalis* decreased with increase in temperature, which is attributed to the increased metabolic activities in life stages. Similar temperature-dependent immature survival and development in other ladybeetles have also been reported (Obrycki and Tauber, 1982; Ponsonby and Copland, 1996; Bind, 1998; Srivastava, 2000; Omkar and Pervez, unpubl). The rate of development of immature stages was directly proportional, whereas development time was inversely proportional to temperature. A linear increase in the rate of development when correlated with temperature agrees with the findings on *Hippodamia convergens* Guerin-Meneville (Obrycki and Tauber, 1982), *Hippodamia sinuata* Mulsant (Michels and Behle, 1991) and *Propylea dissecta* (Mulsant) (Omkar and Pervez, unpublished) but disagrees with those on *Epilachna varivestris* Mulsant (Mellors and Bassow, 1983) and *Chilocorus nigritus* (Fabricius) (Ponsonby and Copland, 1996), which show a sigmoidal relationship.

The decrease in incubation period with the increase in temperature may be attributed to the accelerated embryogenesis, which probably caused early hatching of neonate instars. The decreased larval period of *C. transversalis* with increase in temperature

may be attributed to the increased metabolic activities and to the possible increased feeding activity of the instars, providing more nutrients for rapid development. The development was fastest in the second instar, followed by first, third and fourth. A relatively long duration of first instars may be attributed to the small size and less activity than the second instars. Duration of fourth instar was highest amongst other instars, which may be attributed to the high feeding activity in a bid to store certain food reserves for the necessary energy requirement in the pupal phase (James, 2001).

First instar was most vulnerable stage at each temperature and suffered maximum mortality. Low temperature proved most detrimental for them, as their survival was lowest at 20 °C. Larval survival was highest at 27 °C. Temperatures above 27 °C increased the larval mortality, which signifies high sensitivity and less tolerance of larvae to high temperatures. High temperatures, especially 35 °C, led to increased prey mortality with some aphids becoming alate. These aphids appeared to be distasteful or difficult to capture by the predator and thus deterred their feeding. Thus, possibly the food also becomes a limiting factor at 35 °C resulting in decreased prey consumption and increased larval mortality. Though larval survival reduced at 35 °C, the successful development of pre-imaginal stages clearly indicates that the predator can even withstand the marginal temperatures above it. Owing to high mortality of *A. gossypii* at 35 °C, either a different species of aphid is required, which can tolerate such extremes or cycling fluctuating temperatures may be used to evaluate the contribution of higher temperatures towards development and immature survival of the ladybeetle. The decreased larval survival at low temperatures may possibly be due to limited predation and decreased metabolic rate. Temperatures below 20 °C might not be suitable for instars because of poor survival (32.20% at 20 °C). The increased mortality with high and low temperatures was also reported for other ladybeetles (Naranjo *et al.*, 1990; Miller, 1992; Ponsonby and Copland, 1996; Lamana and Miller, 1998).

The highest survival rates of pupae may be attributed to their thick pupal case, which provides enough protection from the unfavourable abiotic stressors. Though rise in a temperature expedited the developmental rate, it could not alter the ratio of time spent at different stages, which suggests the presence of an innate ratio between the consecutive developmental periods of immature stages. Adult emergence and growth index were significantly affected by change in temperature, which suggests the reduced plasticity of *C. transversalis*. This relatively lesser ecological plasticity as compared to other cosmopolitan aphidophagous *C. septempunctata* (Wheeler and Hoebeke, 1995) may be a reason why the predator has not successfully invaded in different biogeographical areas. Both the parameters (adult emergence and growth index) were highest at 27 °C revealing it to be the optimum temperature for the mass rearing of the predator.

Effect of temperature on reproduction

Fecundity increased with increase in temperature upto 27 °C and thereafter decreased. Significantly high fecundity at 27 °C reveals that temperature optimization directly influences the progeny production in the ladybeetle. This may be due to the development

and maturation of ovaries, resulting in increased ovariole production. Omkar and Pervez (2002) emphasized a probable early maturation of the gonads in *Micraspis discolor* (Fabr.) at optimal temperature to be a crucial reason for a lesser pre-oviposition period and the shortening in time between first egg laid and the oviposition peak. A significant decrease in fecundity was noted at 30 °C. Anderson and Hales (1986) reported that a decrease in the fecundity may possibly be attributed to the increased fat body accumulation, which occurred due to the increased predatory activity at high temperature. The increased fat body affected ovariole formation by limiting the space.

Egg viability in *C. transversalis* increased with increase in temperature upto 27 °C and decreased thereafter, emphasizing 27 °C to be optimum for maximum viability. The decreased hatching rate at higher and lower temperatures may be due to increased egg mortality. Ponsonby and Copland (1998) surmised that reduced viability in eggs at low temperature was perhaps due to inhibition of spermatogenesis or owing to the probable sperm mortality in the spermathecae of females. Least percent viability was experienced at 35 °C in the present investigation, as some of the batches failed to hatch and turned flaccid and reddish yellow. It appeared as if they were burnt due to high temperature. This indicates that temperatures 35 °C and above are detrimental for the egg viability. Present study reports a more viable fecundity in *C. transversalis*, ranging 76.37 to 90.06% than in *C. sexmaculata*, ranging 27.70 to 64.10% (Bind, 1998).

Thus, it may be inferred that significant effects of constant temperatures on different life parameters in *C. transversalis* reveal it to be less ecologically plastic rather than other cosmopolitan aphidophagous ladybeetles. The optimum constant temperature (in terms of immature survival, development and reproductive performance) for the mass raring of *C. transversalis* was found to be 27 °C. Temperature at both the extremes, i.e. upto 20 and 35 °C resulted in the decreased larval survival, adult emergence, growth index, fecundity and viability. The development rate increased linearly with the increase in temperature.

ACKNOWLEDGEMENT

The authors are thankful to Indian Council of Agricultural Research, New Delhi, for financial assistance.

REFERENCES

Agarwala, B. K. and Bardhanroy, P. (1999) Numerical response of ladybird beetles (Coccinellidae : Coleoptera) to aphid prey (Homoptera: Aphididae) in a field bean in northeast India. *J. Appl. Ent.* **123**: 401–405.

Agarwala, B. K. and Ghosh, A. K. (1988) Prey records of aphidophagous Coccinellidae in India. A review and bibliography. *Trop. Pest Manag.* **34**: 1–14.

Anderson, J. M. E. and Hales, D. F. (1986) In: *Coccinella repanda. Diapause?*, Hodek, I. (Ed). Ecology of Aphidophaga, Academia Prague & Dr. W. Junk: Dordrecht, 233–238.

Babu, A. (1999) Influence of prey species on feeding preference, post embryonic development and reproduction of *Coccinella transversalis* F. (Coccinellidae: Coleoptera). *Entomon* **24**: 221–228.

Bind, R. B. (1998) Bioecology and behaviour of a ladybird beetle, *Cheilomenes* (=*Menochilus*) *sexmaculata* (Fabricius) (Coleoptera: Coccinellidae). *Ph.D. Thesis*, University of Lucknow, Lucknow, p. 164.

Debraj, Y. and Singh, T. K. (2000) Field recognition of the different developmental stages of an aphidophagous coccinellid predator, *Coccinella transversalis*. *Ann. Plant Prot. Sci.* **8**: 242–244.

Evans, E. W. (2000) Egg production in response to combined alternative food by the predator *Coccinella transversalis*. *Ent. Exp. Appl.* **94**: 141–147.

Frazer, B. D. and McGregor, R. R. (1992) Temperature dependent survival and hatching rate of eggs of seven species of Coccinellidae. *Can. Ent.* **124**: 305–312.

George, P. J. E. (2000) Prey preference of ladybird beetle, *Coccinella transversalis* Fabricius (Coleoptera: Coccinellidae). *Insect Environ.* **6**: 124–125.

Jalali, S. K., Singh, S. P. and Biswas, S. R. (1999) Effect of temperature and female age on the development and progeny production of *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae). *Entomon* **24**: 293–296.

James, B. E. (2001) Contribution on certain aspects of bioecology and behaviour of a ladybeetle, *Coccinella transversalis* Fabricius (Coccinellidae: Coleoptera). *Ph.D. Thesis*, University of Lucknow, pp. 190.

Joshi, S., Ballal, C. R. and Rao, N. S. (1999) Biotic potential of three coccinellid predators on six different aphid hosts. *J. Ent. Res.* **23**: 1–7.

Lamana, M. L. and Miller, J. C. (1998) Temperature dependent development in an Oregon population of *Harmonia axyridis* (Coleoptera: Coccinellidae). *Environ. Entomol.* **27**: 1001–1005.

Mellors, W. K. and Bassow, F. E. (1983) Temperature dependent development of Mexican bean beetle (Coleoptera: Coccinellidae) immatures on snap bean and soyabean foliage. *Ann. Ent. Soc. Amer.* **76**: 692–698.

Michels, G. J. Jr. and Behle, R. W. (1991) A comparison of *Coccinella septempunctata* and *Hippodamia convergens* larval development on greenbugs at constant temperatures. *The Southwestern Entomologist* **16(1)**: 73–80.

Miller, J. C. (1992) Temperature-dependent development of the convergent lady beetle (Coleoptera : Coccinellidae). *Environ. Entomol.* **21**: 1139–1142.

Naranjo, S. E., Gibson, R. L. and Walgenbach, D. D. (1990) Development, survival and reproduction of *Scymnus frontalis* (Coleoptera: Coccinellidae), an imported predator of Russian wheat aphid, at four fluctuating temperatures. *Ann. Ent. Soc. Amer.* **83**: 527–531.

Obrycki, J. J. and Tauber, M. J. (1982) Thermal requirement for the development of *Hippodamia convergens* (Coleoptera: Coccinellidae). *Ann. Ent. Soc. Amer.* **75**: 678–683.

Omkar, and Bind, R. B. (1993) Records of aphids-natural enemies complex of Uttar Pradesh. II. The Coccinellids. *J. Adv. Zool.* **14**: 96–99.

Omkar, and James, B. E. (2001) Searching and feeding efficacy of *Coccinella transversalis* Fabricius on brinjal aphid, *Aphis gossypii* Glover. *Biol. Mem.* **27**: 20–26.

Omkar, and Pervez, A. (2000) Biodiversity of predaceous coccinellids (Coleoptera: Coccinellidae) in India: A review. *J. Aphidol.* **14(1&2)**: 41–66.

Omkar, and Pervez, A. (2002) Influence of temperature on age-specific fecundity of a ladybeetle, *Micraspis discolor* (Fabricius). *Insect Sci. Applic.* **22(1)**: 61–65.

Ponsonby, D. J. and Copland, M. J. W. (1996) Effect of temperature on development and immature survival in the scale insect predator, *Chilocorus nigritus* (F.) (Coleoptera : Coccinellidae). *Biocontrol Sci. Tech.* **6**: 101–109.

Ponsonby, D. J. and Copland, M. J. W. (1998) Environmental influences on fecundity, egg viability and egg cannibalism in the scale insect predator, *Chilocorus nigritus*. *BioControl* **43**: 39–52.

Srivastava, S. (2000) Certain aspects of bioecology and ethology of a ladybeetle. *Coccinella septempunctata* Linnaeus (Coccinellidae : Coleoptera). *Ph.D. Thesis*, Department

of Zoology, University of Lucknow, Lucknow, p 160.
Veeravel, R. and Baskaran, P. (1996) Temperature-dependent development, adult longevity, fecundity and feeding potential of two coccinellid predators under laboratory conditions. *Entomon* **21**: 13–18.
Wheeler, A. G. Jr. and Hoebeke, E. R. (1995) *Coccinella novemnotata* in Northeastern North America: Historical occurrence and current status (Coleoptera : Coccinellidae). *Proc. Ent. Soc. Washington* **97**: 701–716.
Yang, X., MioQing, S., ZhenZhong, S. and Jiwen, X. (1998) Effects of temperature on experimental population of *Chilocorus kuwanae* Silvestri. *Zool. Res.* **19**: 39–44.

(Received 27 January 2003; accepted 27 October 2003)

ENTOMON 29(1): 25–30 (2004)
Article No. ent.29104

Scanning electronmicroscopic study of the cuticular structures on the head of *Gerris* sp. (Hemiptera: Gerridae) and *Cloeon* sp. (Ephemeroptera: Baetidae)

S. Gupta* and A. Gupta

Department of Ecology and Environmental Science, Assam University, Silchar 788 011, Assam, India

ABSTRACT: The cuticular structures on the head of *Gerris* sp. and *Cloeon* sp. have been studied by scanning electron microscopy. While the head cuticle of *Gerris* sp. is clothed with dense hairs and a variety of sensory structures, the cuticle of *Cloeon* sp. is comparatively simple. It is beset with numerous scales and only two types of microstructure. The probable functions of these cuticular structures have been discussed. © 2004 Association for Advancement of Entomology

KEYWORDS: Sensilla trichoidea, sensilla basiconica, sensilla placoidea

INTRODUCTION

The cuticle is involved in the construction of all sense organs in insects except the proprioceptors. Thus, cuticle dominates the arthropod ways of life (Neville, 1975). Cuticular structures such as different types of sensilla, their position and orientation provide a basis for understanding the relationship between their morphology and function. While the functional morphology of various cuticular sensory receptors has been extensively studied in terrestrial insects, comparable information available on the aquatic forms is considerably less (Dahl, 1978; Kapoor and Zachariah, 1984; Gupta *et al*., 1999, 2000; Gupta and Gupta, 1996, 1998; Gupta, 1998a,b). The present paper attempts to describe the various sensory structures on the head cuticle of two insects, *viz*., *Gerris* sp. (Hemiptera: Gerridae) and *Cloeon* sp. (Ephemeroptera: Baetidae) by scanning electron microscopy. Scanning electron microscopy greatly clarifies the orientation, structure and arrangement of complex cuticular components because of its large depth of field and high resolving power (Schmidt and Smith, 1987).

*Corresponding author

© 2004 Association for Advancement of Entomology

TABLE 1. Comparative morphometric data of the cuticular structures on the head of *Gerris* sp. and *Cloeon* sp.

Types of cuticular structures	Length in μm ($\overline{X} \pm$ SD)	Diameter/width of the sensilla in μm ($\overline{X} \pm$ SD)	Diameter of the socket in μm ($\overline{X} \pm$ SD)
Gerris sp.			
1. Long hairs	26.9 ± 2.05	1.68 ± 0.51	—
2. Short hairs	1.7 ± 0.19	0.52 ± 0.09	—
3. Sensilla trichoidea	86.3 ± 6.83	2.33 ± 0.19	19 ± 0.79
4. Sensilla basiconica	0.85 ± 0.04	1.9 ± 0.29	4.6 ± 0.54
5. Sensilla placoidea	—	4.9 ± 0.24	—
Cloeon sp.			
1. Sensilla trichoidea	14.53 ± 0.7	1.23 ± 0.18	—
2. Short pegs	2.35 ± 0.2	0.93 ± 0.22	—

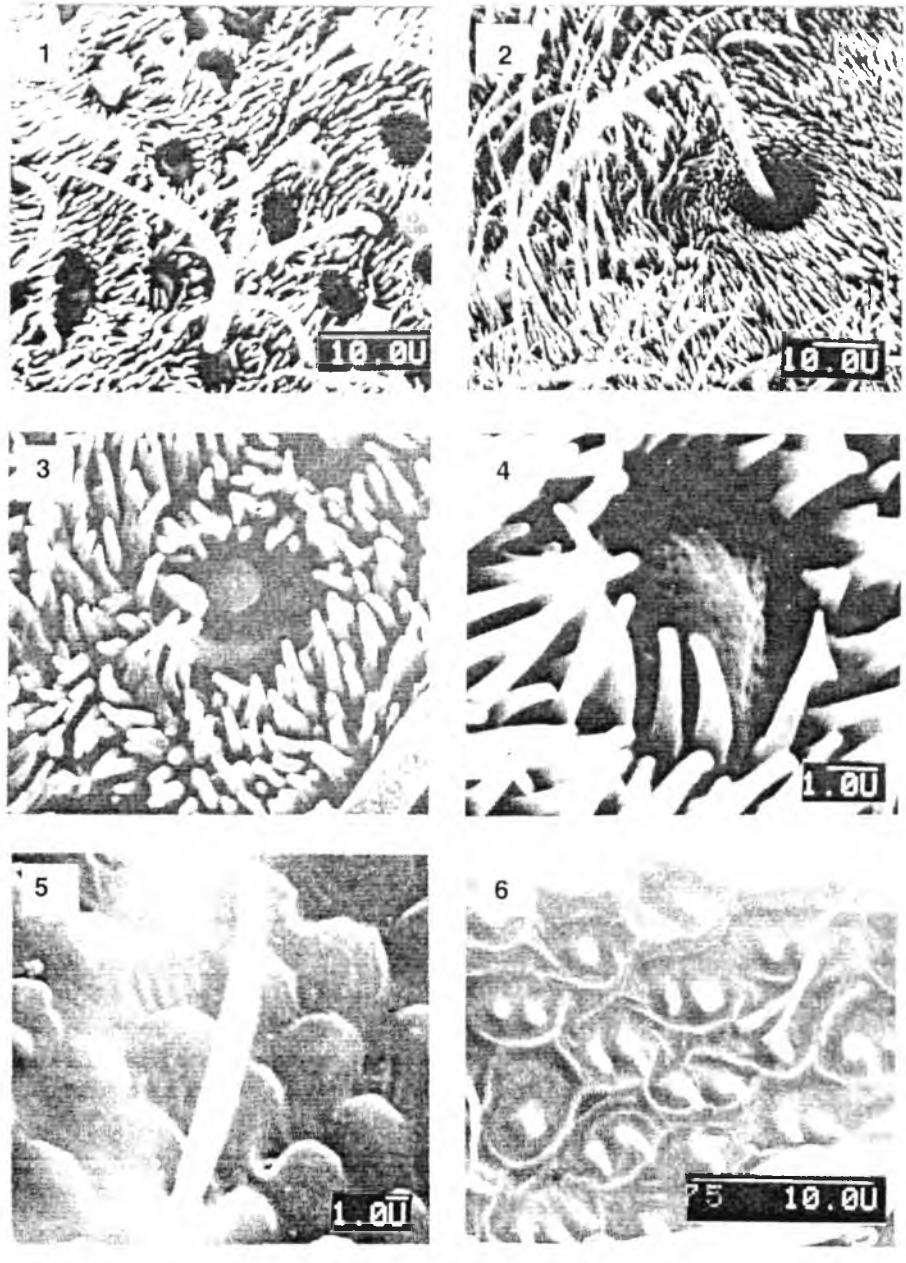
MATERIAL AND METHODS

Larvae of *Cloeon* sp. and a few adults of *Gerris* sp. were collected from Ward Lake, a small artificial lake in Shillong (25°34′ N, 91°52′ E), Meghalaya State, India. Severed heads of *Cloeon* sp. and *Gerris* sp. were fixed for 2 h in 2.5% glutaraldehyde and post-fixed for 2 h in 2% osmium tetroxide, both fixatives buffered with 0.1 M cacodylate. They were dehydrated in graded concentrations of acetone, dried in a 'Critical Point Drying' apparatus, mounted on brass stubs and coated with gold in a fine coat Ion Sputter JFC 1100 (Gupta *et al.*, 2000). The specimens were examined and photographed in a JSM 35 CF Scanning Electron Microscope.

RESULTS

The comparative morphometric data on the cuticular structures on the head of *Gerris* sp. and *Cloeon* sp. are depicted in Table 1. Head cuticle of *Gerris* sp. has a dense growth of long and short unsocketed hairs and sensory structures. The dense short hairs are curved and slightly tapering with a blunt tip while the long hairs are slender, bent and with a pointed tip. Three types of sensilla are strewn among these dense hairs. The first type is sensilla trichoidea that are long, tubular, bent and have a tapered tip. Each sensillum is surrounded by short unsocketed hairs or microtrichia (Fig. 2). Sensilla type 2 are sensilla basiconica, which are small pegs set in wide circular sockets. The rim of the socket is flush with the peg (Fig. 3). Sensilla type 3 are sensilla placoidea that are more or less round, dome shaped structures (Fig. 4). Both sensilla type 2 and sensilla type 3 are lodged in pits, which are strewn among a profusion of short dense hairs (Figs 1, 3 and 4).

The head cuticle of *Cloeon* sp. is beset with numerous scales with a few sensilla trichoidea strewn among them (Fig. 5). The other major cuticular microstructures



FIGURES 1–4. *Gerris* sp.: Head cuticle (Fig. 1); Sensilla trichoidea (Fig. 2); Sensilla basiconica (Fig. 3); sensilla placoidea (Fig. 4).
FIGURES 5–6. *Cloeon* sp.: Scales on the head cuticle (Fig. 5); Short pegs (Fig. 6).

include short, blunt pegs set on the scales in the anterior part of the head cuticle (Table 1). These pegs have somewhat dilated bases with blunt tips (Fig. 6).

DISCUSSION

Presence of dense clothing hairs as seen on the head cuticle of *Gerris* sp. is the characteristic feature of terrestrial insects where the cuticle besides providing protection also serves the function of waterproofing (Neville, 1975). As *Gerris* lives on the water surface, an unwettable surface is necessary for respiratory plastrons where dense hairs slightly curved at the tip hold thin film of gas and resist compression of the gas film (Daly *et al.*, 1998). Further, these hairs overcome surface tension forces at air-water interphase, prevent water from flooding the trachea, acts as a suitable hydrofuge device to prevent drowning of the insect, and subsequently provide heat insulation (Neville, 1975; Gupta *et al.*, 1999). The long, curved and tapered sensilla trichoidea on the head cuticle of *Gerris* are supposed to be trichobothria and apparently receive ultrasonic vibrations as observed in *Cediopsylla simplex* (Amrine and Lewis, 1986). A similar view is shared by Callahan (1975) for long and tapered sensilla trichoidea. Generally long delicate hairs respond to slightest force such as minor air pressure changes and the orientation of the hairs possibly aid in the determination of the direction of the source. The short hairs are spaced either to form multiple resonating units over the entire surface of the sensillum or somehow function to dampen the vibrations, thus isolating the vibration of each sensilla trichoidea (Amrine and Lewis, 1986). The role of the second type of sensilla, the short pegs, is to function as mechanoreceptors and they are likely to exhibit a directional characteristic response (Gewecke, 1970). Several dome shaped placoidea found among the trichobothrium and sensory pegs are similar to the dome shaped placoidea found in the antennae of the wasp *Polister matricus* which are referred to as a scent detection mechanism of the insect (Callahan, 1975). In the head cuticle of *Cloeon* sp., scales serve as frictional resistance to escape from predators and facilitate the transport of loose substrate (Schmalfuss, 1978a,b; Gupta and Gupta, 1998). The sensilla trichoidea strewn among the scales are likely to be mechanoreceptors because of their slender pliable setae and sockets that allow movement in all directions. Further, they may be used for cleaning detritus and other debris from the head surface (Honegger, 1977; Zack and Bacon, 1981; Gupta, 1998b). No specific function could be assigned to the short blunt pegs on the scales. These are similar to the sensilla basiconica in their morphology but lack sockets. Unsocketed sensilla, especially sensilla trichoidea have been shown to be non-innervated (Schmidt and Smith, 1985). However, the dilated basal areas of these pegs are suggestive of a possible secretory role.

It has been observed that the nature of cuticular modifications of both the insects are entirely different although they inhabit the same ecosystem. This may be due to the fact that the two insects occupy two different niches of the same system and need to modify their cuticular structure for monitoring and responding to changes in the environment. Hence, the position and orientation of different types of sensilla and

other cuticular structures provide a basis for understanding the relationship between their morphology and function.

ACKNOWLEDGEMENT

The authors wish to thank Professor D.T. Khathing, Director, Regional Sophisticated Instrumentation Center, North Eastern Hill University, Shillong for his help and encouragement.

REFERENCES

Amrine, J. W. and Lewis, R. E. (1986) The topography of the exoskeleton of *Cediopsylla simplex* (Baker, 1895) (Siphonaptera: Pulicidea): the thorax, abdomen and associated appendages. *J. Parasitol.* **72(1)**: 71–87.

Amrine, J. W. and Lewis, R. E. (1978) The topography of the exoskeleton of *Cediospsylla simplex* (Baker, 1895) (Siphonaptera: Pulicidae): the head and its appendages. *J. Parasitol.* **64(2)**: 343–358.

Callahan, P. S. (1975) Insect antennae with special reference to the mechanism of scent detection and the evolution of the sensilla. *Int. J. Insect Morphol. Embryol.* **4**: 381–430.

Dahl, C. (1978) Scanning electron microscopic studies of epicuticular patterns in mosquito larvae (Diptera, Calicidae) and their use as taxonomic characters. *Zoologica Scripta* **7**: 209–217.

Daly, V. H., Doyen, T. J. and Purcell, H. A. (III) (1998) *Introduction to Insect Biology and Diversity*, Oxford University Press: p 680.

Gewecke, M. (1970) Another wind sensitive receptor in locusts. *Nature* **225**: 1263–1264.

Gupta, S. (1998a) External morphology of the antennal sensilla of the imago of *Cloeon* sp. (Ephemeroptera: Baetidae) as revealed by scanning electron microscopy. *J. Animal Morphol. Physiol.* **45(1&2)**: 142–144.

Gupta, S. (1998b) External morphology of the interommatidial hairs of *Cloeon* sp. (Ephemeroptera: Baetidae) as revealed by SEM. *Geobios New Reports* **17**: 63–67.

Gupta, S. and Gupta, A. (1996) Antennal sensilla of the subimago of *Cloeon* sp. (Ephemeroptera: Baetidae). *J. Anim. Morphol. Physiol.* **43**: 137–138.

Gupta, S. and Gupta, A. (1998) Cuticular sensory structures on the cerci of the nymphs and adults of mayfly *Cloeon* sp. (Ephemeroptera: Baetidae). *Proc. Nat. Acad. Sc. India* **68(B) III & IV**: 319–321.

Gupta, S., Gupta, A. and Meyer-Rochow, V. B. (1999) Cuticular microstructures of abdominal tergites and sternites of *Cloeon* sp. (Ephemeroptera: Baetidae) during post embryonic development. *Entomologica Fennica* **10**: 51–59.

Gupta, S., Gupta, A. and Meyer-Rochow, V. B. (2000) Post embryonic development of the lateral eye of *Cloeon* sp. (Ephemeroptera: Baetidae) as revealed by scanning electron microscopy. *Entomologica Fennica* **11**: 89–96.

Honegger, H. W. (1977) Interommatidial hair receptor axons extending into the ventral nerve cord in the cricket *Gryllus campestris*. *J. Comp. Physiol.* **130**: 49–62.

Kapoor, N. N. and Zachariah, K. (1984) Scanning and transmission electron microscopy of the developmental stages of the flower-shape sensillum of the stonefly nymph, *Thaumatoperla alpina* Burns and Neboiss (Plecoptera: Eustheniidae). *Int. J. Insect Morphol. Embryol.* **13(9)**: 177–189.

Neville, A. C. (1975) Biology of the arthropod cuticle. *Zoophysiol. Ecol.* **4/5**: 1–448.

Schmalfuss, H. (1978a) Structure, patterns and function of cuticular terraces in recent and fossil arthropods. 1. Decapod crustaceans. *Zoomorphologie* **90**: 19–40.

Schmalfuss, H. (1978b) Morphology and function of cuticular miscroscales and corresponding structures in terrestrial isopods (Crust., Isop., Oniscoidea). *Zoomorphologie* **91**: 263–274.

Schmidt, J. M. and Smith, J. J. B. (1985) The ultrastructure of the wings and the external sensory morphology of the thorax in female *Trichogramma minutum* Riley (Hymenoptera: Chalcidoidea: Trichogrammatidae). *Proc. R. Soc. Lond.* **B 224**: 287–313.

Schmidt, J. M. and Smith, J. J. B. (1987) The external sensory morphology of the legs and hair-plate system of female *Trichogramma minutum* Riley (Hymenoptera: Trichogrammatidae). *Proc. R. Soc. Lond.* **B 232**: 323–366.

Zack, S. and Bacon, J. (1981) Interommatidial sensilla of the preying mantids: their central neural projections and role in head-cleaning behaviour. *J. Neurobiol.* **12**: 55–65.

(Received 20 October 2003; accepted 14 January 2004)

ENTOMON **29(1)**: 31–38 (2004)
Article No. ent.29105

Mark-recapture studies for evidence of memorized site-fidelity in *Anopheles culicifacies* Giles, in Garhwal region

N. Pemola Devi and R. K. Jauhari*

Parasitology Laboratory, Department of Zoology, D.A.V.(P.G.) College, Dehra Dun - 248001
Email: jauharirk@hotmail.com

ABSTRACT: A mark-recapture experiment was carried out in Kotdwar (Pauri-Garhwal) locality to determine whether *Anopheles culicifacies* exhibits memory by investigating if the individuals would return to the habitat where they had obtained. In all, 577 specimens were collected from both human dwelling and cattle shed then marked with different colours according to whether they were caught in human dwelling, 'human fed' or in cattle sheds, 'cattle fed' from fixed habitat. Thereafter they were released from another location. Over 420 specimens of *An. culicifacies* were collected over the next 10 days of the experiment and examined individually whether they were marked ones or not. In total, 5.71% of released mosquitoes were recaptured; of these 72.7% (24 of 33) returned to the habitat where they were first caught, thus demonstrating site-fidelity. Results further indicated that mosquitoes seeking cattle were more faithful (75.0%, 18 of 24) in returning to their original habitat than those seeking human habitation (66.6%; 6 of 9).
© 2004 Association for Advancement of Entomology

KEYWORDS: Mark-release, *Anopheles culicifacies*, site-fidelity, Garhwal region

INTRODUCTION

Insects are able to learn many things especially resource location, oviposition, mating etc. as seen in various social insects. The ability of bees to memorize the location of nectar sources is well known, but many other insect groups are also capable of memory. Thus, insects are capable to combine processes learned from previous experience to meet a new problem. Many herbivorous and parasitic insects can associate odour or visual cues with food sources and oviposiition sites (Papaj and Lewis, 1993). Evidences for the existence of memory in mosquito and blood feeding insects are scanty. Nutsathapana *et al.* (1986) demonstrated a mark-release-recapture

*Corresponding author

© 2004 Association for Advancement of Entomology

of host-preference heterogeneity of *Anopheles minimus* and showed a significant tendency to return to the type of host upon which they were first caught. Charlwood *et al.* (1988) found that *An. farauti* in Papua, New Guinea made long flights to oviposition sites before returning 'home' to blood feed. There are other examples of male *Aedes taeniorhynchus* (Nielsen and Nielsen, 1953) and *Culex torrentium* (Service, 1994) in which the specimens returned to swarm at the same location, suggesting 'spatial memory'. Hii (1985) determined the tendency of *Anopheles balabacensis* to return to sites of first capture when faced with a choice of different hosts. Further Mwandawiro *et al.* (2000) showed that Japanese encephalitis vectors *Culex tritaeniorhynchus, Cx. gelidus* and *Cx. vishnui* were more likely to feed upon the host species on which they had first fed. Recently, McCall *et al.* (2001) demonstrated the site-fidelity of *Anopheles arabiensis* in northern Tanzania and Ulloa *et al.* (2002) studied about the host-fidelity of *An. vestitipennis* in Chiapas, Mexico.

In our study, *Anopheles culicifacies* is selected because of its distribution throughout India except some areas of Northeastern region i.e. Manipur (Nagpal and Sharma, 1995 and Malhotra and Mahanta, 1994). It is well-know primary vector of malaria in India and several neighbouring countries. The species has been identified as a complex of five cryptic species — species A, B (Green and Miles, 1980), species C (Subbarao *et al.*, 1983), species D (Vasantha *et al.*, 1991) and Species E (Kar *et al.*, 1999) on the basis of different genotypes. In Garhwal region, this species occurred throughout the southwestern part within the elevational range of 230 to 1300 m (Rao *et al.*, 1973 and Bhat, 1975) and is believed to consist 2 sibling species A and B (Subbarao *et al.*, 1999). It is a must at the present to undertake studies on dispersal of mosquito for formulating the most appropriate control strategy as well as understanding disease epidemiology. However, some considerable works on dispersal of *An. culicifacies* are of Russell *et al.* (1944); Curtis and Rawlings (1980); Rawlings *et al.* (1981); Rawlings and Davidson (1982) and Sadanandane *et al.* (1993).

The main purpose of the present study is to investigate whether the primary vector of malaria, *Anopheles culicifacies* also had the ability of site fidelity based on mark-released and recaptured study. Emphasis has also been given whether individual *An. culicifacies* would preferentially return to habitat from where they had previously rest and obtained a blood meal.

MATERIALS AND METHODS

Study area

The study was carried out at Kotdwar locality situated in the southwestern part of Garhwal region of Uttaranchal state. It lies between latitude 29°45′N and 78°31′E longitudes. The selected area is a foothill region, at 395 m (altitude) occupied with mid dense groove of various trees and surrounded by verdant fields. The climate in this area is hot, subhumid with a rainy season extending from June through August and an intervening dry season. The study was carried out during the months August and September 2002, post monsoon season when the density of mosquito was comparatively higher.

(A) Mark-release experiment

Two experiments of mark-release-recapture were carried out during two consecutive months August and September 2002. For each experiment we selected two-fixed habitats — one human dwelling and other was cattle shed of nearly 1 km apart. From each habitat, mosquitoes were collected during morning (05:00–06:00 h) and evening hours (07:00–08:00 h) by a pair of collector using aspirator and flash light (WHO, 1975). Soon after collection the collected specimens were brought to the laboratory and sorted out if it was *An. culicifacies* or not bye using Keys and Catalogues (Christophers, 1933; Wattal and Kalra, 1961 and Nagpal and Sharma, 1995). Inspite of consideration whether the mosquito specimens were blood fed or not, we selected all the female mosquitoes. Those mosquitoes that were difficult to identify in field conditions were immobilized by petroleum ether.

Just after the collection the mosquito specimens were separated into two groups - one 'human-fed' collected from human dwelling and the other 'cattle-fed' from cattle sheds. During both the experiments i.e. I and II, the collection of mosquitoes was done 5 days continuously to obtain good amount of specimens, by keeping inside the rearing cages. Next 6th day all the collected specimens were ready for marking by two different colour according to the habitat from where they have obtained — red for 'human-fed' and green for 'cattle-fed'. The process of marking is based on dust-storm technique using insufflator with mobile insects keeping in the cage (WHO, 1975). After marking, all the marked mosquitoes were released from another location at a distance of about 1 km from the original two habitats.

(B) Recapture

Recapturing of released mosquitoes was started during morning and evening hours following the same techniques from the 7th day of experiments and continued till 10 days from the original selected habitats — human dwelling and cattle shed. Soon after recapture all the collected mosquitoes were narcotized and again brought to the laboratory. Firstly, all the mosquitoes were sorted out species wise and thereafter the specimens belong to *An. culicifacies* were separated by examining the marked colours using ultra-violet light.

(C) Data analysis

Site-fidelity was estimated by the number of marked mosquitoes returning to feed/rest at the original habitat type. Difference in proportions of mosquitoes returning to the original habitat was examined with chi-square (χ^2) test with Yates' correction.

RESULTS

In the experiment I, 137 *An. culicifacies* mosquitoes from selected human habitat, whereas 215 from the cattle habitat were collected. The resulting human to cattle habitat ratio was 1 : 1.56, while in the experiment II, out of 225 mosquitoes, 107 preferred human habitat and 118 cattle habitat in a ratio of 1:1.10. Overall, in both the

TABLE 1. Showing recapture rate and site fidelity of *Anopheles culicifacies* in different habitats at Kotdwar locality of Garhwal region

No. of Expts.	Habitats	No. of released mosquitoes	Recapture rate (%)	Site fidelity			
				Human dwelling	Cattle shed	χ^2 $df = 1$	P
Expt. I	Human dwelling	137	3.64%	60% (3/5)	40% (2/5)	1.70	0.20
	Cattle shed	215	6.04%	15.3% (2/13)	84.6% (11/13)		
Expt. II	Human dwelling	107	3.73%	75.0% (3/4)	25.0% (1/4)	0.54	0.50
	Cattle shed	118	9.32%	36.0% (4/11)	6.36% (7/11)		
Expt. I & II	Human dwelling	244	3.68%	66.6% (6/9)	33.3% (3/9)	3.87	0.05
	Cattle shed	333	7.2%	25.0% (6/24)	75.0% (18/24)		

experiments I and II, more mosquitoes were collected in the cattle shed (333) than in the human habitat (244) with a ratio of 1:1.36 (total = 577).

Site fidelity of mosquitoes was estimated by recapturing marked mosquitoes returning to the original habitat for feeding/resting. Other species of Anophelines caught during the collection in good number were *An. annularis*, *An. maculatus*, *An. stephensi*, *An. subpictus* and *An. vagus*. In experiment I, most recapture was made on the 13th and 14th day of the experiment whereas in experiment II, 8th and 9th day produced large amount. Table 1 shows the number of specimens released, recapture rate and rate of site fidelity in different selected habitats. During the experiments I and II, the recapture rates were 3.64 and 3.73% from human dwelling and 6.04 and 9.32% from cattle shed respectively. In both the experiments, 33 specimens belonging to *An. culicifacies* (5.71%) were recaptured. Regardless of where they were first caught, 3 of 12 (36.37%) mosquitoes returned to hauman dwelling and 21 of 33 (63.64%) to cattle sheds. Over all, 72.7% of *An. culicifacies* returned to the original habitats showing memorized site-fidelity. In experiment I, 60% (3 of 5) of *An. culicifacies* were returned to the original habitat i.e. human dwelling, whereas 84.6% (11 of 13) of mosquitoes collected from cattle shed have been found to return to their original habitat — the cattle shed. Data from the experiment I ($\chi^2 = 1.70$, $P = 0.20$) showed a tendency for site preference in those marked *An. culicifacies* specimens which returned to the habitat from where they were initially obtained. In experiment II, 75% (3 of 4) mosquitoes returned to the original habitat human dwelling and 63.6% (7 of 11) mosquito returned to original habitat cattle shed. Thus the mosquitoes showed the tendency of site-fidelity but not at significant level ($\chi^2 = 0.54$; $P = 0.50$). After pooling, *An. culicifacies* mosquitoes seeking animal host/habitat were recorded as more faithful (75.0%, 18 of 24) in returning to their original habitats than those mosquitoes seeking human host/habitat (66.6%, 6 of 9). The combined data of experiments I and II showed a significant level of heterogeneity for site preference/site-fidelity ($\chi^2 = 3.87$; $P = 0.05$).

DISCUSSION

In the present investigation released *An. culicifacies* mosquitoes showed a significant tendency to return to the habitat in which they had previously feed/rest. The results support the possibility of 2 subpopulations of *An. culicifacies* exhibiting finding of Subbarao *et al.* (1999) in having the higher preference for either human dwellings or cattle sheds. Earlier findings on biting and resting behavior of *An. culicifacies*-predominantly zoophagic nature and preferred cattle sheds for resting (Jambulingam *et al.*, 1984 and Pal, 1945) and thus are in accordance with our findings. There is a little similarity between the findings as recorded by Sugunal *et al.* (1983) and Joshi *et al.* (1988) with regard to findings of difference in host preference in morphologically indistinguishable subspecies of *Anopheles culicifacies* A and B and species A more anthropophagic than the species B. The segregation of feeding/resting behaviour with >50% (75% and 66.67% on animal and human dwellings respectively) of mosquitoes returning for feeding/resting on the same habitat from which they

were first captured, indicates site-specific tendencies. Charlwood *et al.* (1988) while working on *Anopheles farauti* in Papua, New Guinea reported similar findings of memorized home range. In Malaysia, studies on *An. balabacensis*, determine the tendency to return to sites of first capture when faced with a choice of different hosts (Hii, 1985). Further, it was suggested by Hii that host preferences in some Anophelines might be influenced by previous feeds, with females more likely to feed on the same host species at a subsequent feed (Hii and Vun, 1987 and Hii *et al.*, 1991). Host-preference heterogeniety in *An. minimus* in Thai village (Nutsathapana *et al.*, 1986) have similar finding of significant tendency to return to the type of host upon which they were first caught. Recent studies on *An. arabiensis* females (McCall *et al.*, 2001) showed significant tendency of site-fidelity regarding return to the original house prior to the next blood meal. The findings report by Ulloa *et al.* (2002) on *An. vestitipennis* showed similarity indicating that mosquitoes seeking animal hosts were more faithful (80.48%) in returning to their original host than those seeking human hosts (63%). However, Loong *et al.* (1990) and Chiang *et al.* (1991) reported that there was no evidence to suggest the existence of subpopulation of *Anopheles maculatus* biting different preferred host either indoor or outdoor during their studies in Malaysia.

So, our results support the evidence of spatial memory, leading to site-fidelity or homing behaviour on *An. culicifacies* and it can be concluded that mosquitoes may be capable of learning through experience. The present investigation very clearly indicates return of mosquito specimens to houses after marking in which they had previously successfully obtained a blood meal. Moreover, there has been exerting of local environment that might influence the return of marked specimens.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. P. K. Das, Director, Vector Control Research Centre (ICMR), Pondicherry and Dr. B. K. Tyagi, Deputy Director (SG), Centre for Research in Medical Entomology (ICMR), Madhurai (TN) for their valuable suggestions. The financial assistance rendered by Department of Science and Technology, (Govt. of India) New Delhi is also highly acknowledged.

REFERENCES

Bhat, H.R. (1975) A survey of Haematophagour Arthropods in Westerns Himalayas, Sikkim and Hill Districts of West Bengal: Records of Mosquitoes Collected from Himalayan Region of Uttar Pradesh with Ecological Notes. *Indian J. Med. Res.* **63(11)**: 1583–1608.

Charlwood, J.D., Graves, P.M. and Marshall, T. F. de C. (1988) Evidence for a 'memorized' host range in *Anopheles farauti* females in Papua New Guinea. *Med. Vet. Entomol.* **2**: 101–108.

Chiang, G.L., Loong, K.P., Chan, S.T., Eng, K. L. and Yap, H.H. (1991) Capture-recapture studies with *Anopheles maculatus* Theobald (Diptera: Culicidae) the vector of malaria in Peninsular Malaysia. *Southeast Asian J. Trop. Med. Pub. Hlth.* **22(4)**: 643–647.

Christophers, S.R. (1933) *The fauna of British India including Ceylon and Burma. Diptera, Family Culicidae, Tribe Anophelini*, Taylor and Francis: London, p 371.

Curtis, C.F. and Rawlings, P. (1980) A preliminary study of dispersal and survival of *Anopheles culicifacies* in relation to the possibility of inhibiting the spread of insecticide resistance. *Ecol. Entomol.* **5**: 11–17.

Green, C.A. and Miles, S.J. (1980) Chromosomal evidence for sibling species of the malaria vector *Anopheles culicifacies Giles*. *J. Trop. Med. Hygn.* **83**: 75–78.

Hii, J.L.K. (1985) Evidence for the existence of genetic variability in the tendency of *Anopheles balabacensis* to rest in houses and to bite man.. *Southeast Asian J. Trop. Med & Pub. Hlth.* **16**: 173–182.

Hii, J.L.K. and Vun, Y.S. (1987) The influence of a heterogeneous environment on host feeding behaviour by *Anopheles balabacensis*.. *Trop. Biomed.* **4**: 67–70.

Hii, J.L.K., Chew, M., Sang, V.Y., Munstermann, L.E., Tan, S.G., Paniyim, S. and Yasothornsrikul, S. (1991) Population genetic analysis of host seeking and resting behaviours in the malaria vector *Anopheles balabacensis*. *J. Med. Entomol.* **28**: 675–684.

Jambulingam, P., Sabesan, S., Vijayan, V.A., Krishnamoorthy, K., Gunasekaran, K., Rajendran, G., Chandrahas, R.K. and Rajagopalan, P.K. (1984) Density and biting behaviour of *Anopheles culicifacies* Giles in Rameswaram Island (Tamil Nadu). *Indian J. Med. Res.* **80**: 47–50.

Joshi, H., Vasantha, K., Subbarao, S.K. and Sharma, V.P. (1988) Host feeding patterns of *Anopheles culicifacies* species A and B.. *J. Amer. Mosq. Cont. Assoc.* **4(3)**: 248–251.

Kar, I., Subbarao, S.K., Eapen, A., Ravindran, A., Satyanarayana, T.S., Raghvendra, K., Nanda, N. and Sharma, V.P. (1999) Evidence for a new malaria vector species, species E within the *Anopheles culicifacies* complex (Diptera: Culicidae). *J. Med. Entomol.* **36(5)**: 595–600.

Loong, K.P., Chiang, G.L., Eng, K.L., Chan, S.T. and Yap, H.H. (1990) Survival and feeding behaviour of Malaysian strain of *Anopheles maculatus* Theobald (Diptera: Culicidae) and their role in malaria transmission. *Trop. Biomed.* **7**: 71–76.

Malhotra, P.R. and Mahanta, H.C. (1994) Checklist of mosquitoes of North-east India (Diptera: Culicidae). *Oriental Insects* **28**: 125–149.

McCall, P.J., Mosha, F.W., Njunwa, K.J. and Sherlock, K. (2001) Evidence for memorized site-fidelty in *Anopheles arabiensis*. *Trans. Royal Soc. Trop. Med. Hygn.* **95**: 587–590.

Mwandawiro, C., Boots, M., Tuno, N., Suwonkerd, W., Tsuda, Y. and Takagi, M. (2000) Heterogeneity in the host preferences of Japanese encephalitis vectors in Chiang Mai, northern Thailand. *Trans. Royal Soc. Trop. Med. Hygn.* **94**: 238–242.

Nagpal, B.N. and Sharma, V.P. (1995) *Indian Anophelines*. Oxford and IBH Publishing Co. Pvt. Ltd.: New Delhi, p 1–416.

Nielsen, E.T. and Nielsen, A.T. (1953) Field observations on the habits of *Aedes taeniorhynchus*. *Ecology* **34**: 141–156.

Nutsathapana, S., Sawasdiwongphorn, P., Chitprarop, U and Cullen, J.R. (1986) A mark-release-recapture demonstration of host-preference heterogeneity of *Anopheles minimus* Theobald (Diptera: Culicidae) in a Thai village. *Bull. Ent. Res.* **76**: 313–320.

Pal, R. (1945) On the bionomics of *Anopheles culicifacies* Giles Part III. The behaviour of adults. *J. Mal. Inst. Ind.* **6(2)**: 217–238.

Papaj, D.R. and Lewis, A.C. (1993) *Insect Learning: Ecological and Evolutionary Perspectives*. Chapman and Hall: New York, p 374–386.

Rao, T.R., Dhanda, V., Bhat, H.R. and Kulkarni, S.M. (1973) A survey of Haematophagous Arthropods in Western Himalayas, Sikkim and Hill districts of West Bengal. A General Account.. *Indian J. Med. Res.* **61(10)**: 1421–1461.

Rawlings, P. and Davidson, G. (1982) The dispersal and survival of *Anopheles culicifacies* Giles (Diptera: Culicidae) in a Sri Lankan village under malathion spraying. *Bull. Ent. Res.* **72**: 139–144.

Rawlings, P., Curtis, C.F., Wickramasinghe, M.B. and Lines, J. (1981) The influence of age and season on dispersal and recapture of *Anopheles culicifacies* in Sri Lanka. *Ecol. Entomol.* **6**: 307–319.

Russell, P.F., Kinpe, F.W., Rao, T.R. and Putnam, P. (1944) Some experiments on flight range of *Anopheles culicifacies*. *J. Expt. Zool.* **97**: 135–163.

Sadanandane, C., Gunasekaran, K., Jambulingam, P. and Das, P.K. (1993) Studies on dispersal of malaria vectors in a hilly tract of Koraput district, Orissa state, India. *Southeast Asian J. Trop. Med. Pub. Hlth.* **24(3)**: 508–512.

Service, M.W. (1994) Male swarming of the mosquito *Culex (Culex) torrentium* in England. *Med. Vet. Entomol.* **8**: 95–98.

Subbarao, S.K., Nanda, N. and Raghavendra, K. (1999) Malariogenic stratification of India using *Anopheles culicifacies* sibling species prevalence.. *ICMR Bull.* **29(7)**: 75–80.

Subbarao, S.K., Vasantha, K., Adak, T. and Sharma, V.P. (1983) *Anopheles culicifacies* complex. Evidence for a new sibling species, species C.. *Ann. Entomol. Soc. Amer.* **76**: 985–988.

Suguna, S.G., Tewari, S.C., Mani, T.R., Hiriyan, J. and Reuben, R. (1983) *Anopheles culicifacies* species complex in Thenpenniyar riverine tracts, Tamil Nadu, India. *J. Med. Res.* **77**: 455–459.

Ulloa, A., Arredondo-Jimenez, J.I., Rodriguez, M.H. and Fernandez-Salas, I. (2002) Mark-recapture studies of host selection by *Anopheles* (Anopheles) *vestitipennis*.. *J. Amer. Mosq. Cont. Assoc.* **18(1)**: 32–35.

Vasantha, K., Subbarao, S.K. and Sharma, V.P. (1991) *Anopheles culicifacies* complex: population cytogenetic evidence for species D (Diptera: Culicidae). *Ann. Entomol. Soc. Amer.* **84**: 531–536.

Wattal, B.L. and Kalra, N.L. (1961) Region-wise pictorial keys to the female Indian *Anopheles*.. *Bull. Nat. Soc. Ind. Mal. Mosq. Born. Dis.* **10**: 55–138.

WHO, (1975) Manual on practical entomology in malaria vector bionomics and organization of antimalaria activities. Part I and part II, Offset Publication.

(Received 16 August 2003; accepted 12 January 2004)

ENTOMON **29(1)**: 39–43 (2004)
Article No. ent.29106

A revised key to the world species of *Lisotrigona* moure (Hymenoptera : Apoidea : Apidae) with description of a new species from India

T. Jobiraj* **and T. C. Narendran**

Systematic Entomology Laboratory, Department of Zoology, University of Calicut, Kerala 673635, India

ABSTRACT: A new species of the stingless bee genus *Lisotrigona* viz., *L. mohandasi* Jobiraj and Narendran sp. nov. (Apinae: Meliponini) is described and illustrated. A revised key to the species of *Lisotrigona* is also provided.
© 2004 Association for Advancement of Entomology

KEYWORDS: *Lisotrigona*, new species, key to species, Apoidea.

INTRODUCTION

Stingless bees of the genus *Lisotrigona* Moure (1961) are uncommon in the Indian subcontinent. They are similar to *Pariotrigona*, but differ most notably by the short, linear malar space, the converging inner compound eye margins and in the acute base of the marginal cell. Moure (1961) and Michener (1990, 2000) gave useful accounts for the identification of *Lisotrigona*. Recently Engel (2000) revised the Indo-Malayan meliponine genus *Lisotrigona* with two new species. Hence we describe a new species, namely *Lisotrigona mohandasi*, and provide a revised key to the species of *Lisotrigona*.

A revised key to the world species of *Lisotrigona* moure

1. Clypeus entirely yellow; face with yellow markings; mesoscutum black with thin yellow margins bordering tegulae; body size relatively large (4–4.2 mm) ..... *L. carpenteri* Engel
- Clypeus dark brown to black; face without yellow markings; mesoscutum dark brown, without lateral yellow markings; body size relatively small (3–3.7 mm) 2
2. Punctures of mesoscutum exceedingly minute and somewhat faint 3

*Corresponding author

© 2004 Association for Advancement of Entomology

- Punctures of mesoscutum small and strong ..... *L. furva* Engel

3. Integument of head, thorax and metasoma generally brown to dark brown; gena impunctate; pubescene on clypeus simple and hypoepimeron without hairs; metanotum finely imbricate ..... *L. cacciae* (Nurse)

- Integument of head and thorax coal black and metasoma brown; gena sparsely punctate; pubescence on clypeus plumose and hypoepimeron with minute, scattered hairs; metanotum reticulate anteriorly ..... *L. mohandasi* sp. nov.

***Lisotrigona mohandasi* sp. nov. (Figs 1–4)**

Holotype: F (w): TL = 3 mm, HW = 1.28, HL = 1.083, SL = 0.389, FL = 0.91, FWL = 2.6, FWW = 0.96, HWL = 1.77, EL = 0.86, EW = 0.35, POL = 0.3, OOL = 0.2.

Colour: Integument: Entirely black except for the following parts: basal part of mandibles dull brown, rest of mandibles and glossa dull yellow; labial palpi whitish yellow; labrum dull brown; clypeus dark brown; scape yellowish brown with apical quarter dark brown; pedicel and flagellum light brown; eyes brown; ocelli with dark brown tint under certain illuminations; tegulae hyaline with brownish black spot anteriorly; axillary sclerites yellow; wing veins pale yellow to light brown, membrane hyaline; legs dark brown except for yellow trochanters and tarsal segments; metasoma brown to dark brown.

Pubescene: Pubescence generally silvery or white. Labrum with a few long, white hairs. Clypeus with small, simple, white hairs scattered over surface, and hairs become plumose at margins; facial hairs white, not obscure integument, long and plumose; pilosity on ocellar and vertex area minute, white, with a few scattered long hairs. Antennae covered with minute, suberect hairs over surface; gena anteriorly with minute, simple, silvery, scattered pilosity; postgena with a few hyaline to silvery, long, scattered hairs. Labial palpal segments 1 and 2 each with a couple of long, simple, sinous hairs. Pilosity on mesoscutum as on gena, scattered and antereolaterally minutely plumose. Pubescence of scutellum longer than on scutum, silvery and becoming progressively longer posteriorly. Metanotum with minute, simple and transparent hairs very widely scattered. Pre-episterum with short plumose, silvery, appressed hairs not obscuring integument, such hairs becoming simple and longer on rest of mesepisternum; hypoepimeron with minute and scattered hairs; metepisternum with silvery hairs on upper part only. Propodeal lateral surface with moderately long, white plumose hairs; posterior surface with scattered, simple hairs, basal area without pubescence. Pubescence on legs silvery to white except for tarsal segment pilosity reflecting brown to golden tints. Metasomal $T_1 - T_4$ without pubescence except widely scattered, simple hairs along apical margins, such hairs progressively more numerous on apical terga, also sparsely present on central discs of $T_5 - T_6$, such hairs widely scattered on sterna.

Head: Width in anterior view a little more than 1.33× distance between front ocellus and lower clypeal margin (84 : 63) (Fig. 2); maximum width of head at level of posterior margin of eyes 6× distance between front ocellus and occipital margin (51 : 8.5) (Fig. 4). Relative measurements of POL = OOL = 12.8; mandibles sparsely punctate, edenate and rounded along their outer margins; clypeus and face with widely scattered, minute punctures; integument between punctures glabrous; punctures becoming slightly dense and somewhat faint on vertex. Gena and postgena impunctate and glabrous. Scape of antenna not reaching front ocellus; space less than half of flagellum. Relative length: maximum width antennal segments; scape = 2.5:5.6; Pedicel = 6:5, F_1 = 5:5.5, F_2 = 5:6, F_3 = 5:6, F_4 = 5:6, F_5 = 5:6, F_6 = 4:6, F_7 = 5:6, F_8 = 5.5:6, F_9 = 6:9, F_{10} = 8:5 (Fig. 3). Eyes more or less parallel to each other, simple and glabrous; relative length : breadth of eyes in lateral view = 34.5 : 14 (Fig. 1).

Thorax: Maximum width between tegulae to length of thorax = 18:28; mesoscutum with exceedingly minute and faint punctures separated by 2× puncture width, interspaces glabrous; tomentose bands absent; punctures on scutellum sparse and more developed than on mesoscutum; metanotum glabrous, reticulate, reticulations well developed on anterior half. Episternum glabrous and impunctate except for upper half of pre-episternum; anterior quarter of mesepisternum with faint, minute punctures; propodeum finely reticulate.

Legs rather long, strong and well developed; hind tibia glabrous, posterior marginal hairs simple and moderate, rastrellum not well developed; keirotrichia well developed as in figure (Fig. 1), corbicula glabrous and striatoreticulate (more striated); hairs on hind metatarsi bristle like, upper apical angle of hind tibia rounded.

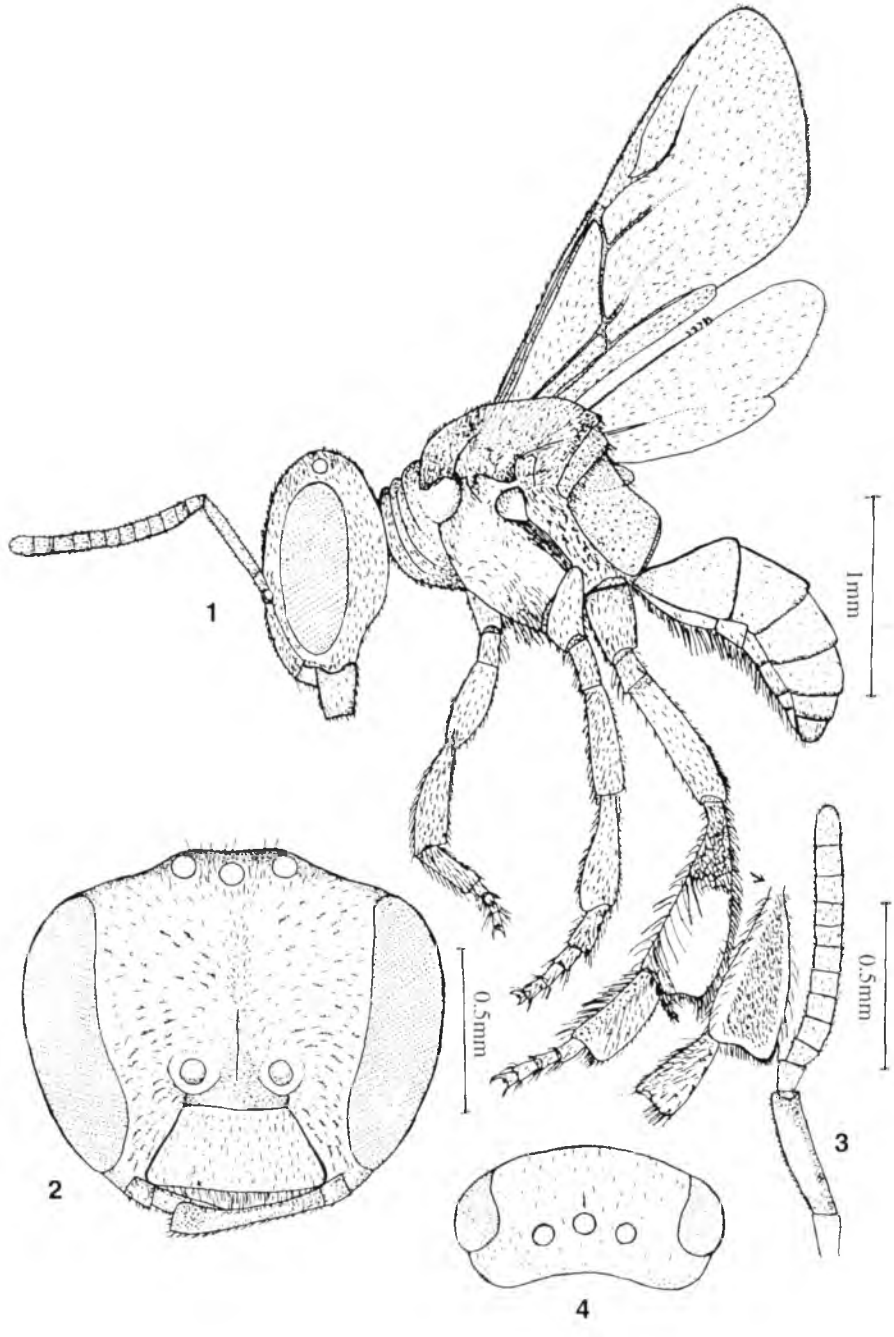
Tegulae and axillary sclerites minutely and sparsely punctate; forewing venation as in figure (Fig. 1). Relative measurements of forewing length: Its maximum width = 104 : 83.5; minute hairs distributed throughout wing membrane; marginal cell acute at apex, submarginal cells not represented; wing venation faintly marked on hind wing; hamuli–5 (Fig. 1).

Metasoma: Metasoma glabrous and impunctate but apical margins finely imbricate, middle terga broader than anterior and posterior tergites. Sternal plates sparsely and minutely punctate.

Male: Unknown.

Materials examined: Holotype: F: India, Kerala, Kerala Forest Research Institute (Peechi), K. Mohandas, 3-IV-2000; *Paratypes:* 2 F: Same data as that of holotype. (Deposited in Calicut University Zoology Department).

Etymology: The species is named after Dr. K. Mohandas who collected the specimens.



FIGURES 1–4. *Lisotrigona mohandasi* sp. nov. Female. 1. Body (Profile), 2. Head: Front view, 3. Antenna, 4. Head: Dorsal view.

Flower Record: *Tectona grandis.*

Habitat: Undisturbed area.

Discussion: This species closely resembles *L. cacciae* (Nurse) in general characters but differs mainly in the following characters: 1. Integument of head and thorax coal black and metasoma brown (In *L. cacciae* integument dark brown); 2. Mandibles dull yellow to brown (In *L. cacciae* mandibles yellow); 3. Gena sparsely punctate (In *L. cacciae* gena impunctate); 4. Hairs on clypeus plumose (In *L. cacciae* hairs on clypeus simple); 5. Hypoepimeron with pubescence (In *L. cacciae* hypoepimeron without hairs); 6. Metanotum reticulate anteriorly (In *L. cacciae* metanotum finely imbricate).

Abbreviations

F = Female, TL = Total length, HW = Head width, HL = Head length, SL = Scape length; FL = Flagellar length, FWL = Forewing length; FWW = Forewing width, HWL = Hind wing length, EW = Eye width, EL = Eye length, POL = Post ocellar length, OOL = Ocellocular length.

ACKNOWLEDGEMENTS

We are grateful to Dr. Michael S. Engel, Department of Entomology, University of Kansas Natural History Museum, for critically reviewing the manuscript. His suggestions are incorporated in the text. We are also grateful to Dr. Charles D. Michener, University of Kansas, Natural History Museum, Kansas, USA for providing his valuable research publications. Thanks are also due to the authorities of the University of Calicut for the facilities provided.

REFERENCES

Engel, M. S. (2000) A review of the Indo-Malayan meliponine genus *Lisotrigona*, with two new species (Hymenoptera: Apidae). *Oriental Insects* **34**: 229–237.

Michener, C. D. (1990) Classification of the Apidae (Hymenoptera). *Univ. Kansas Sci. Bull.* **54**: 75–163.

Michener, C. D. (2000) *The Bees of the World*, Johns Hopkins University Press: Baltimore, USA.

Moure, J. S. (1961) A preliminary supra-specific classification of the old world meliponine bees (Hymenoptera: Apoidea). *Studia Entomol.* **4**: 181–242.

(Received 3 December 2002; accepted 29 July 2003)

ENTOMON 29(1): 45–50 (2004)
Article No. ent.29107

Efficacy of new insecticides and neem formulations in the management of the citrus leaf miner, *Phyllocnistis citrella* Stainton (Phyllocnistidae: Lepidoptera)

P. D. Kamala Jayanthi* and Abraham Verghese

Division of Entomology and Nematology, Indian Institute of Horticultural Research, Hesseraghatta Lake PO, Bangalore 560089, India

ABSTRACT: The efficacy of new insecticides against citrus leaf miner, *Phyllocnistis citrella* Stainton was compared with commonly used insecticides along with neem-based formulations. Among different insecticides evaluated cypermethrin, fenvalerate, monocrotophos, chlorpyrifos, imidacloprid, λ-cyhalothrin and profenofos + cypermethrin were found effective in preventing fresh mining by *P. citrella*. Neem formulations *viz.*, neem seed kernel extract, azadirachtin were found superior in causing high mortality of leaf miner larvae. The adult emergence was also found lowest in all synthetic insecticidal and neem seed kernel extract treated plants. The present study clearly showed that under heavy infestation, use of synthetic insecticides is necessary to prevent reinfestation of leaf miner. However, the neem formulations can be used as follow-up sprays under heavy infestation and as prophylactic sprays during new flush emergence. © 2004 Association for Advancement of Entomology

KEYWORDS: Citrus leaf miner, insecticides, neem formulations, *Phyllocnistis citrella*

INTRODUCTION

The citrus leaf miner, *Phyllocnistis citrella* Stainton (Phyllocnistidae: Lepidoptera) is an important pest of citrus in nurseries, and on new flushes in orchards. Of the total damage caused by the pest complex of citrus, nearly 30% is attributed to the leaf miner (Anonymous, 1984). Leaf miner damage, predisposes the leaves to canker caused by *Xanthomonas citri* Hasse. Several workers have evaluated insecticides to control *P. citrella* (Borle and Khosdaskar, 1977; Batra and Sandhu, 1986; Bhumannavar, 1987). There are insecticides to suppress the population of *P. citrella*, but most are ineffective against eggs and early instars. Hence, reinfestation of leaf miner occurs within a week after application (Boulahia *et al.*, 1996). The present study was carried out as it was felt

*Corresponding author

© 2004 Association for Advancement of Entomology

necessary to study the efficacy of new insecticides available in the market and neem based formulations for preventing reinfestation as well as for overall effectiveness.

MATERIAL AND METHODS

Investigations were carried out in citrus (acid lime) at the Indian Institute of Horticultural Research, Bangalore. Four synthetic pyrethroids *viz.*, cypermethrin 0.0125%, fenvalerate 0.005%, λ-cyhalothrin 0.0025% and profenofos + cypermethrin 0.022%; imidacloprid 0.005%; neem based formulations *viz.*, neem seed kernel extract (NSKE) 5%, azadirachtin (oil based) 300 ppm (3 ml/lt), and azadirachtin 1500 ppm (3 ml/lt); conventional insecticides *viz.*, monocrotophos 0.05% and chlorpyrifos 0.05% along with control were screened for their efficacy against *P. citrella*. The experiment was laid out in a Randomised Block Design, and the treatments were replicated thrice. Each tree was considered a unit of replication. The first trial was conducted during June–July, 1999 and the second during October–November, 1999, coinciding with the emergence of new flush. Three sprays were given at 15 days interval starting from the emergence of new flush.

Observations were recorded at weekly interval on total number of live mines, dead mines and mines with emerged holes from ten randomly selected shoots per plant. Discoloured larvae were considered dead and those with their normal look were considered live. After third spray, the plants were graded for leaf damage by visual scoring of newly sprouted leaves based on per cent leaf damage from ten randomly selected shoots per plant. In each shoot, eight leaves were taken from the tip and each leaf was graded for per cent severity of the damage ranging from zero (no leaf miner incidence) to 100 (total damage with leaf curled and twisted). The data of two trials were subjected to 'pooled analysis of variance' (Little and Hill, 1978).

RESULTS AND DISCUSSION

Effect of insecticides on live mines

Seven days after the first spray, there was no significant difference in the number of live mines in the untreated control and the treatment neem seed kernel extract 5%. All other treatments showed significantly lesser number of live mines and were on par with each other (Table 1). At 14 days after first spray, the treatment *viz.*, chlorpyrifos, Imidacloprid, monocrotophos, λ-cyhalothrin, fenvalerate and cypermethrin were found significantly superior in bringing down the number of live mines per shoot (Table 1).

At seven days after second spray, fenvalerate, chlorpyrifos, cypermethrin, λ-cyhalothrin, profenofos + cypermethrin, monocrotophos, imidacloprid, neem seed kernel extract and azadirachtin 300 ppm recorded lower number of live mines per shoot and found significantly superior to remaining treatments. At 14 days after second spray, azadirachtin 300 ppm, neem seed kernel extract, imidacloprid, chlorpyrifos, λ-cyhalothrin, monocrotophos, fenvalerate and azadirachtin 1500 ppm recorded significantly lower number of live mines per shoot (Table 1).

TABLE I. Effect of different insecticides on citrus leaf miner, *P. citrella* incidence - Pooled date (Trial I and II).

Treatments	I Spray						II Spray						III Spray
	7 DAS			14 DAS			7 Das			14 DAS			14 DAS
	L	D	E	L	D	E	L	D	E	L	D	E	% Leaf damage
NSKE 5%	1.70^{d}	0.63^{abc}	0.23^{abc}	0.78^{cd}	0.52^{ab}	0.15^{ab}	0.82^{ab}	0.30^{a}	1.37^{ab}	0.40^{ab}	0.18^{a}	7.74^{ab}	
Azadirachtin 330 ppm	0.51^{b}	1.17^{abc}	0.38^{c}	0.62^{bc}	0.25^{cd}	0.57^{bc}	0.63^{ab}	0.65^{a}	0.67^{ab}	0.67^{ab}	0.38^{ab}	0.45^{cd}	10.74^{b}
Azadirachtin 1500 ppm	0.29^{ab}	1.45^{ab}	0.15^{abc}	0.98^{d}	0.38^{bcd}	0.32^{bc}	1.48^{bc}	0.55^{ab}	1.15^{ab}	1.15^{ab}	0.35^{ab}	0.58^{cd}	10.14^{b}
Imidacloprid 0.005%	0.23^{ab}	0.15^{c}	0.08^{ab}	0.27^{a}	0.65^{a}	0.30^{bc}	1.17^{bc}	0.62^{a}	0.70^{ab}	0.70^{a}	0.53^{a}	0.32^{ab}	11.17^{b}
Monocrotophos 0.05%	0.22^{ab}	1.02^{abc}	0.31abc	0.32ab	0.45^{bcd}	0.18^{a}	0.68^{ab}	0.20^{b}	0.18^{ab}	1.30^{ab}	0.30^{b}	0.23^{ab}	4.84^{b}
λ-cyhalothrin 0.0025%	0.06^{a}	1.03^{cd}	0.00^{a}	0.30^{ab}	0.48^{bc}	0.47^{abc}	0.62^{ab}	0.48^{ab}	0.28^{a}	1.55^{bc}	0.33^{ab}	0.20^{a}	6.55^{ab}
Profenfos + Cypermethrin 0.022%	0.19^{ab}	1.62^{a}	0.08^{ab}	0.80^{bc}	0.37^{bcd}	0.25^{bc}	0.83^{ab}	0.33^{ab}	0.38^{ab}	1.70^{cd}	0.27^{b}	0.25^{ab}	9.52^{ab}
Chlorpyrifos 0.05%	0.04^{a}	0.95^{bc}	0.15abc	0.25^{a}	0.48^{bc}	0.18^{a}	0.73^{ab}	0.28^{ab}	0.40^{ab}	1.05^{ab}	0.45^{ab}	0.17^{a}	6.76^{ab}
Cypermethrin 0.0125%	0.28^{ab}	1.28^{abc}	0.08ab	0.47^{abc}	0.37^{bcd}	0.33^{bc}	0.70^{ab}	0.23^{ab}	0.32^{ab}	1.72^{bc}	0.40^{ab}	0.33^{ab}	7.10^{ab}
Fenvalarate 0.005%	0.08^{a}	0.75^{cd}	0.08ab	0.33ab	0.83^{a}	0.20^{a}	0.37^{a}	0.48^{ab}	0.30^{ab}	1.77^{bc}	0.30^{b}	0.20^{ab}	5.30^{ab}
Control	1.50^{e}	0.06^{c}	0.45bc	1.78^{e}	0.20^{d}	0.75^{c}	1.78^{c}	0.27^{ab}	0.92^{b}	2.32^{d}	0.07^{c}	0.87^{d}	24.43^{a}

Means within a column having same alphabet are not statistically significant $p = 0.05$; L = Number of live mines; D = Number of dead mines; E = Number of adults emerged.

A perusal of data over two sprays showed that fenvalerate, λ-cyhalothrin, Imidacloprid, chlorpyrifos and monocrotophos were consistently effective in preventing fresh mining for a period of 14 days after spray. However, neem based formulations, *viz.*, neem seed kernel extract, azadirachtin 1500 and 300 ppm had presumably slower action in preventing fresh mining and the efficacy also found variable.

Dead mines after the spray

Profenofos + cypermethrin, azadirachtin 300 and 1500 ppm, monocrotophos and cypermethrin recorded significantly highest number of dead mines at seven days after first spray showing their efficacy in causing larval mortality immediately (Table 1). At 14 days after first spraying, fenvalerate, neem seed kernel extract and Imidacloprid were found significantly superior over other treatments with highest number of dead mines per shoot.

At seven days after second spraying, azadirachtin 300 ppm, Imidacloprid, neem seed kernel extract, azadirachtin 1500 ppm, λ-cyhalothrin, profenofos + cypermethrin and fenvalerate were found statistically superior to remaining treatments with highest number of dead mines (Table 1). At 14 days after second spray, Imidacloprid, neem seed kernel extract, azadirachtin 300 and 1500 ppm, λ-cyhalothrin, chlorpyrifos and cypermethrin were found significantly superior with higher dead mines per shoot (Table 1). Of all treatments, neem formulations *viz.*, neem seed kernel extract, azadirachtin 300 & 1500 ppm were found to be consistently effective in causing the larval mortality and found to be comparable with Imidacloprid, cypermethrin, fenvalerate and λ-cyhalothrin. Whereas, though the other insecticides were found to cause instant mortality immediately seven days after the spray but failed to maintain the same trend upto 14th day after the spray.

Impact of insecticides on adult emergence

The effect of 11 treatments (Table 1) was observed on emergence of adult *P. citrella*. At seven days after the spray, all treatments were found significantly superior with lower adult emergence over untreated control. At 14 days after first spraying, neem seed kernel extract, Azadirachtin 1500 ppm, Imidacloprid, monocrotophos, λ-cyhalothrin, profenofos + cypermethrin, cypermethrin, chlorpyrifos and fenvalerate were found significantly superior with lower adult emergence.

At seven days after second spraying, all treatments were found significantly superior to untreated control with lower adult emergence (Table 1). At 14 days after second spraying, chlorpyrifos, neem seed kernel extract, fenvalerate, profenofos + cypermethrin, λ-cyhalothrin, monocrotophos, cypermethrin and Imidacloprid were found significantly effective treatments with less adult emergence.

A perusal of data over two sprays revealed that of all treatments tried, neem seed kernel extract, cypermethrin, fenvalerate, Imidacloprid, monocrotophos, chlorpyrifos, λ-cyhalothrin profenofos + cypermethrin were found consistently effective in bringing down the adult emergence.

Effect of insecticidal sprays in reducing leaf damage

All treatments were significantly superior in reducing the leaf damage over control. However, the per cent leaf damage was less (4.84%) at 14 days after third spray in the treatment with monocrotophos and was found to be on par with neem seed kernel extract (7.74%), azadirachtin 1500 ppm (10.14%), λ-cyhalothrin (6.55%), chlorpyrifos (6.76%), cypermethrin (7.10%) and fenvalerate (5.30%) (Table 1). This indicates that neem formulations *viz.*, neem seed kernel extract and azadirachtin 1500 ppm were comparable with synthetic insecticides in reducing the leaf damage of *P. citrella*.

The results indicated that the treatments *viz.*, cypermethrin, fenvalerate, imidacloprid, monocrotophos, λ-cyhalothrin and chlorpyrifos, consistently offered effective control of leaf miner upto 14th day after giving the spray, which was evident by minimum number of live mines recorded in these treatments. This reflected the potential of these chemicals in preventing reinfestation. However, the neem formulations *viz.*, neem seed kernel extract and azadirachtin 300 ppm were found to have slower action in preventing fresh mining and were found effective only after second spray has been given. As the latter is IPM compatible, under lower infestation levels, it should be given preference. In case of dead mines, cypermethrin, profenofos + cypermethrin, and monocrotophos were found to be effective in causing instant high larval mortality immediately seven days after first spray has been given. However, by second week, they were found ineffective in causing larval mortality. Whereas, the neem formulations *viz.*, neem seed kernel extract 5%, azadirachtin 300 ppm and 1500 ppm were found consistently effective in causing larval mortality from second spray onwards. Whereas, none of the chemical insecticides were found effective in causing sustained larval mortality except for imidacloprid which showed consistency in causing larval mortality. Further, neem seed kernel extract, imidacloprid, λ-cyhalothrin, monocrotophos, profenofos + cypermethrin, chlorpyrifos, fenvalerate and cypermethrin supported least adult emergence. Hence, it is clear that, the synthetic insecticides *viz.*, cypermethrin and profenofos + cypermethrin were found effective not only by causing high mortality of larvae but also by preventing fresh infestation with least adult emergence. Neem seed extract did not prevent reinfestation, but caused mortality of existing larvae in the mines. This shows that it is a good follow up spray to synthetic insecticides like cypermethrin and profenofos + cypermethrin. Further, cypermethrin recorded lowest leaf damage. Synthetic pyrethroids *viz.*, fenvalerate, cypermethrin and permethrin were recorded greatest reduction in larval population of *P. citrella* on newly flushed citrus trees (Batra and Sandhu, 1986; Bhumannavar, 1987; Radke and Thakare, 1989). Though, neem seed extract, was observed to be less effective in preventing fresh infestation, its capability of causing high larval mortality and least adult emergence makes it an ideal candidate to be integrated with synthetic pyrethroids, thus reducing the possibility of resurgence due to over use of synthetic pyrethroids.

The present study indicates that heavy infestation may warrant use of synthetic pyrethroids as it prevents re-infestation followed by neem based formulations. But, early detection and at lower levels of infestation, azadirachtin or neem seed extract

may be adequate to prevent build up. In fact, at new flushings these botanicals can be advocated as prophylactic sprays.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, Dr. P. P. Reddy, Indian Institute of Horticultural Research for the facilities provided. The assistance given by Mr. B. B. Bopaiah in conducting the study is acknowledged. Thanks are also due to Dr. N. K. Krishna Kumar for his valuable suggestions on the manuscript.

REFERENCES

Anonymous (1984) *Report of National Seminar on Pest Management in Citrus, Cotton, Sugarcane and Sorghum, Progress and Problems held at Nagpur from 5–7th January, 1984.*

Batra, R. C. and Sandhu, G. S. (1986) Chemical control of citrus leaf miner in nursery. *Punjab Horticultural Journal* **26(1/4)**: 31–33.

Bhumannavar, B. S. (1987) Evaluation of pyrethorid compounds against citrus leaf miner, *Phyllocnistis citrella* Stainton (Lepidoptera) on 'coorg mandarin'. *Entomon* **12(3)**: 183–185.

Borle, M.N. and Khosdaskar, P.S. (1977) Pesticidal trials against leaf miner, lemon butterflyand citrus mite inVidarbha region. *International Symposium on Citriculture, Bangalore*, p 35.

Boulahia, S.K., Jerraya, A. and Zaidi, H. (1996) Chemical treatment trials against the citrus leaf miner. *Phyllocnistic citrealla. Fruits* **51(4)**: 223–228.

Little, T.M. and Hill, F.J. (1978) *Agricultural Experimentation*, John Wiley and Sons: New York, Chichester, Brisbane, Toranto, Singapore, p 350.

Nucifera, A. and Nucifera, M.T. (1997) The citrus leaf miner, *Phyllocnistis citrella*Stainton in sicily: development, damages and strategies ofcontro. In integrated contol in citrus fruit crops. In: *Proceedings of the meeting held at Florence, Italy29th August 1996, Bulletin OILB/SROP*, Vacante, V (Ed). **20(7)**: 13–24.

Radke, S.G. and Thakare, A.Y. (1989) Chemical control of citrus leaf miner. *PKV Research Journal* **13(1)**: 44–47.

(Received 24 January 2002; accepted 17 July 2003)

ENTOMON **29(1)**: 51–55 (2004)
Article No. ent.29108

Hitherto unknown Genus *Trigonobothrys* Simon (Theridiidae: Araneae) from India with description of the female of *Trigonobothrys martinae*

A. V. Sudhikumar*, M. J. Mathew and P. A. Sebastian

Division of Arachnology, Department of Zoology, Sacred Heart College, Thevara, Kochi 682013, Kerala, India
Email: avsudhi@rediffmail.com

ABSTRACT: *Trigonobothrys martinae* (Roberts), a rare comb-footed spider, was recorded for the first time from Kuttanad rice agroecosystem of Kerala, India. First description of female of this spider is also provided.
© 2004 Association for Advancement of Entomology

KEYWORDS: *Trigonobothrys martinae*, Kuttanad, Female, First report

INTRODUCTION

The genus *Trigonobothrys* (Simon, 1889) is a small group of comb-footed spiders, represented by only 7 species, distributed in the Palaearctic (3 species) and Oriental (4 species) regions of the world (Platnick, 2003). Members of the genus are characterized by the subovoid carapace; eye region slightly projecting; very high and concave clypeus; subglobose abdomen, sternum broadly produced between coxae IV, leg I longer than IV; female epigynum with a distinct opening, bears a pair of spherical spermathecae and ducts with very minimal coils. Male pedipalp usually bears a large median apophysis, embolus long and forming a circle, conductor with a small projection, and an accessory apophysis usually attached to embolus.

Four species of spiders of the genus *Trigonobothrys* are reported from Oriental region, but none from India so far. Recently three female and two male specimens of *Trigonobothrys martinae* (Roberts) were collected from the rice agroecosystem of Kuttanad, Kerala. On the basis of these specimens *T. martinae* is described and illustrated from India for the first time. Roberts (1983) gave a description of this species based on some male specimens. However taxonomic literature regarding *T. martinae* remains largely incomplete due to the absence of the description of female.

*Corresponding author

© 2004 Association for Advancement of Entomology

During our study we came across three female specimens of *T. martinae*. On the basis of these specimens, a description and illustration of female *T. martinae* is given below.

Abbreviation used are as follows: AME - Anterior median eyes, ALE - Anterior lateral eyes, PME - Posterior median eyes, PLE - Posterior lateral eyes.

Description

Trigonobothrys martinae (Roberts, 1983)

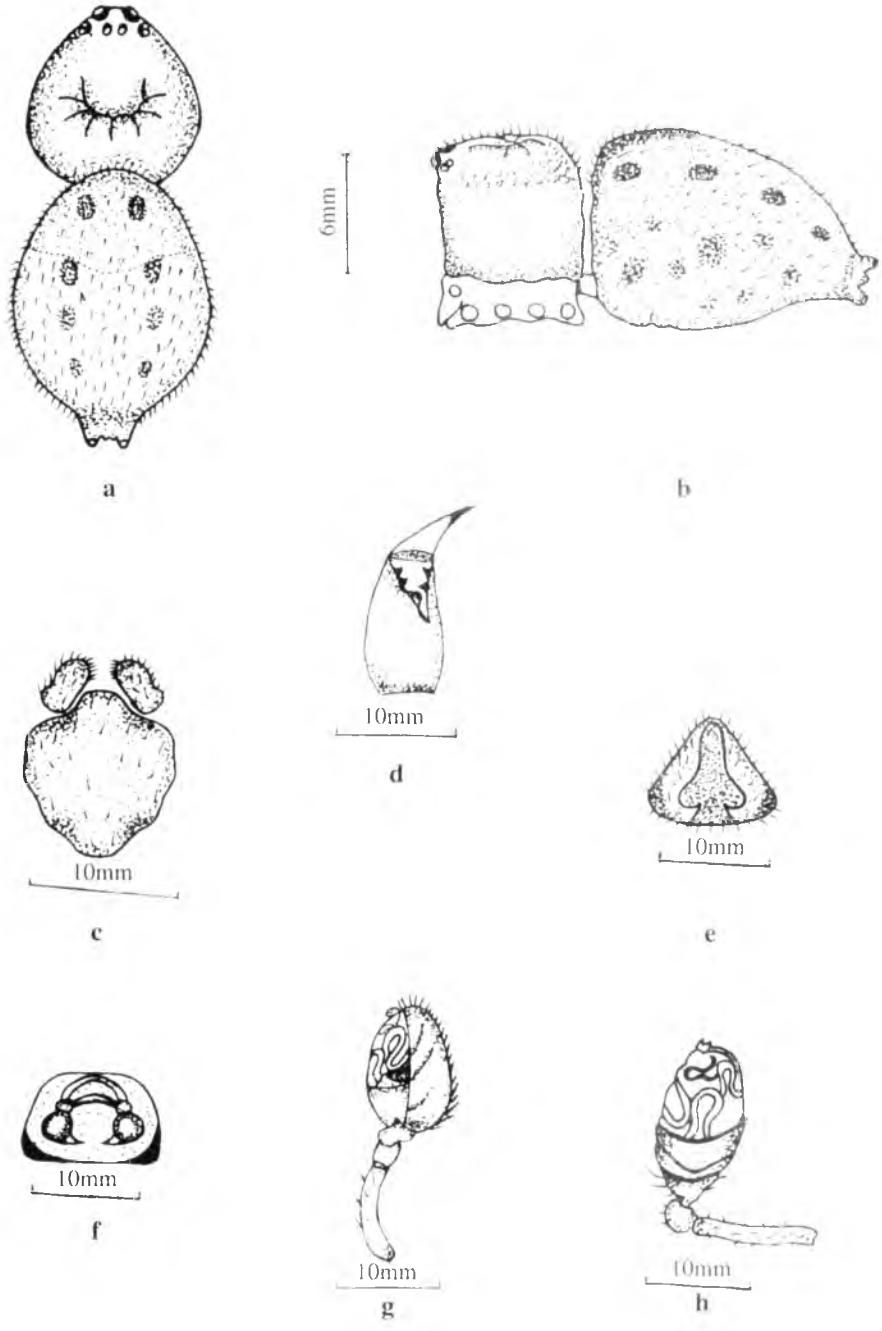
In synonymy with:

T. coreanus (Paik, 1995)	(Yoshida and Ono, 2000).
T. decamaculatus (Chen *et al.*, 1992)	(Zhu, 1998).
T. immaculatus (Zhu, 1998)	(Yoshida, 2002).
T. kayaensis (Paik, 1996)	(Marusik and Koponen, 2000).
T. ruedai (Barrion and Litsinger, 1995)	(Yoshida and Ono, 2000).

Female

Total length 2.42 mm. Cephalothorax 0.85 mm long, 0.83 mm high and 0.93 mm wide, cephalothorax yellowish brown, becoming yellow subposteriomedially and at median base of cephalic region; cephalic region with short hairs, thoracic region with 'U' marking. Eyes 8, clean and homogenous, in two curved rows. Anterior row strongly recurved and shorter than posterior row. Posterior medians larger than laterals. (AME = 0.08, ALE = 0.04, PME = 0.06, PLE = 0.03). Median ocular quadrangle wider in front than behind. Antereomedians posteriorly, laterals at inner aspect and posteromedians anteriorly margined by black. Clypeus very high. Chelicerae yellowish brown, vertical, small, shorter than transverse length of clypeus. Promargin with 3 teeth, subbasal tooth largest and partially projected down ward. Retromargin with 2 diverging teeth as in Fig. d. Maxillae long, pale yellow, inner lateral margin with scopulae. Sternum light yellow, slightly wider than long, anterior margin projecting contiguous to labium, posterior end tapering to narrow blunt point between coxae IV. Legs hirsute, yellow, all longer than length of abdomen, patellae with long apical spine, femur I with a long subapical prolateral spine, tibia I with a sub median prolateral spine. The length of leg segments as in Table 1. Tarsi 3 clawed with a tooth in each superior claw, inferior clawless. Leg formula 1/4/2/3.

Abdomen 1.57 mm long, 1.12 mm wide, 1.13 mm high subglobular, brownish yellow, anterodorsal highly sclerotised, dark brown, sparsely hirsute with brown hair bases, dorsum with longitudinal rows of 4 grey spots, and 4 brown spherical sigilla, laterals each with 10 grey spots. Venter with a wasp head like band anteriorly and 3 transverse rows of 10 yellow brown spots posterior to the epigastric furrow, posterior end of venter with a broad transverse yellow band anterior to the anterior spinnerets. Anterior spinnerets close to each other basally and separated by a "V" shaped space anteriorly. Posterior spinnerets smaller than anterior ones and widely separated from each, closer to the anterior pair than each other. Anal tubercle brown



FIGURES a–h: *Trigonobothrys martinae*. a. Female dorsal view, b. Lateral view, c. Sternum with Labium and Maxillae, d. Chelicerae, e. Epigyne, f. Internal genitalia, g. Pedipalp-lateral view, h. Pedipalp-ventral view.

TABLE 1. Length of leg segments of the spider *Trigonobothrys martinae* (mm)

	Femur		Patella		Tibia		Metatarsus		Tarsus		Total	
	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
I	0.93	0.85	0.48	0.41	0.57	0.52	0.48	0.41	0.31	0.24	2.77	2.43
II	0.67	0.61	0.31	0.26	0.52	0.47	0.44	0.38	0.33	0.26	2.27	1.98
III	0.57	0.51	0.32	0.26	0.48	0.42	0.32	0.28	0.34	0.28	2.03	1.75
IV	0.73	0.69	0.34	0.29	0.71	0.64	0.50	0.45	0.41	0.36	2.69	2.43

usually and yellow apically, with a yellow brown band and two small brown spots dorsal to it. On dorsum, a grey coloured vertical band present in front of spinnerets. Spinnerets visible dorsally. Epigynum simple, anterior margin of orifice tongue like, spermathecae spherical, with coiled spermathecal opening posteriorly leading to indentions in posterior epigynal margin. Epigyne and internal genitalia as in Fig. e and f

Male:

Total length 2.34 mm. Cephalothorax 0.82 mm long, 1.16 mm high and 0.86 mm wide Abdomen 1.52 mm long 1.11 mm wide, 1.14 mm high. Cephalothorax yellowish brown, barrel shaped, with a yellow basal one third with more hairs. Eight eyes in 2 rows, subequal, anterior row strongly recurved, shorter than straight posterior row. (AME = 0.08, ALE = 0.06, PME = 0.07, PLE = 0.07). Clypeus very high, 8.3 times AME diameter. Sternum yellow, as long as wide, with 3 sparse row of hairs near margins, lateral margins straight, posterior tapers to a truncated end, median areas partially raised. Chelicerae smaller than female. Legs yellow, all longer than length of abdomen. Tarsi three-clawed, with a tooth in each superior claw, inferior clawless. Length of leg segments are as in Table 1. Pedipalp yellow, except reddish brown cymbium and light brown tibia. Ejaculatory ducts triple coiled, embolus short, tibia cup like in ventral view as in Fig. g and h.

Abdomen globular, yellow, anterodorsal highly sclrotised, brown, sparsely hirsute with brown hair bases, dorsum with two longitudinal rows of five small grey spots, and 4 brown spherical sigilla, laterals each with 3 grey spots with a broad transverse yellow band anterior to the anterior spinnerets Anterior spinnerets close to each other basally and separated by a "V" shaped space anteriorly. Posterior spinnerets smaller than anterior ones and widely separated from each, closer to the anterior pair than each other. Anal tubercle brown basally and yellow apically, with a yellow brown band and two small brown spots dorsal of it.

Distribution: Kuttanad, Kerala, India; Aldabra, China, Korea, Ryukyu Is., and Philippines.

Natural history: Both male and female were collected from irregular cobwebs of paddy field of Kuttanad (Coll. Sudhikumar A.V; 12.xii.2002). The specimens

are deposited at the Division of Arachnology, Department of Zoology, Sacred Heart College, Kochi 13.

ACKNOWLEDGEMENTS

We are grateful to Rev. Fr. A. J. Saviance CMI, Principal, Sacred Heart College, Thevara, Cochin for providing laboratory facilities. First author is grateful to CSIR for financial assistance.

REFERENCES

Barrion, A. T. and Litsinger, J. A. (1995) *Rice Land Spiders of South and Southeast Asia*. C.A.B. International: Wallingford, UK, 454–455.

Chen, J., Peng, J. P. and Zhao, J. Z. (1992) Two new species of theridiid spider from China (Araneae : Theridiidae). *J. Hubei Univ.* **14**: 270–274.

Marusik, Y. M. and Koponen, S. (2000) New data on spiders (Aranei) from the Maritime Province, Russian Far East. *Arthropoda Selecta* **9**: 55–68.

Paik, K. Y. (1995) Korean spiders of the genus *Dipoena* (Araneae : Theridiidae). I.. *Korean Arachnol.* **11**: 29–37.

Paik, K. Y. (1996) Korean spiders of the genus *Dipoena* (Araneae: Theridiidae). II. Description of two new species. *Korean Arachnol.* **12**: 41–46.

Platnick, N. I. (2003) *The World Spider Catalog, Version 4.0. http://research.amnh.org/entomology/spiders/catalog*, American Museum of Natural History.

Roberts, M. J. (1983) Spiders of the families Theridiidae, Tetragnathidae and Araneidae (Arachnida: Araneae) from Aldabra atoll. *Zool. J. Linn. Soc.* **77**: 217–291.

Simon, E. (1889) Etudes arachnologiques. 21e Memoire. XXXIII. Descriptions de quelques especes receillies au Japon, par A. Mellotee. *Ann. Soc. Ent. Fr.* **8**: 248–252.

Yoshida, H. and Ono, H. (2000) Spiders of the genus *Dipoena* (Araneae, Theridiidae) from Japan. *Bull. Natn. Sci. Mus. Tokyo* **26**: 125–158.

Yoshida, H. (2002) A revision of the Japanese genera and species of the subfamily Hadrotarsinae (Araneae: Theridiidae). *Acta Arachn. Tokyo* **51**: 7–18.

Zhu, M. S. (1998) *Fauna Sinica: Arachnida: Araneae: Theridiidae*, Science Press: Beijing, pp 436.

(Received 21 March 2003; accepted 14 January 2004)

ENTOMON 29(1): 57–62 (2004)
Short Communication No. ent.29109

Male accessory glands in Drosophila: a study on relationship between quantity of secretory proteins and body size

N. L. Lingegowda and S. R. Ramesh*

Drosophila Stock Centre, Department of Studies in Zoology, University of Mysore, Mysore 570006, India
Email: srramesh2000@yahoo.com

ABSTRACT: Male accessory gland secretions, which have a role to play in reproduction, have been investigated. The quantity of male accessory gland secretory proteins in relation to the body size has been studied in nine strains of three species. The study reveled that the quantity of accessory gland secretory proteins are significantly different in different species. There is positive correlation between the body size and the quantity of accessory gland secretory proteins, except in some cases.
© 2004 Association for Advancement of Entomology

KEYWORDS: *Drosophila*, male accessory gland secretions, body size

The accessory gland in the adult male of *Drosophila* is a secretory tissue that produces complex mixture of proteins, carbohydrates, lipids and amino acids (Chen, 1984). These secretions are transferred to the female during copulation along with sperms and have been shown to play an important role in reproduction (Chen, 1996). The secretions elicit post mating behaviour and induce physiological changes in female fly, which includes stimulation of oviposition, egg laying, reduction in female receptivity to courtship, facilitation of sperm storage and maintenance of sperm function in the mated female (c.f. Wolfner, 2002). Age dependent quantitative and qualitative variations in the accessory gland secretions in different species of *Drosophila* have been documented (Wolfner, 1997; Shivanna and Ramesh, 1995a; Ravi Ram and Ramesh, 2002).

Most obvious easily observable and measurable phenotypic trait is directly related to fitness (Chen, 1984; Ruiz *et al.*, 1991; Partridge *et al.*, 1987). Santos *et al.* (1988) have shown that there is an influence of body size on mating success. Body size also influences mating latency, fecundity and other fitness components (Ruiz and Santos, 1989). Extensive work with respect to body size, behaviour, fertility components and role of accessory gland secretory proteins has been carried out (Chapman *et al.*, 2000;

*Correspondent author

© 2004 Association for Advancement of Entomology

TABLE 1. Different species/strains employed in present study

Species/Strains	Stock No.
D. melanogaster	
1. Oregon K	1.002
2. Canton.S	1.006
3. Berlin	1.004
D. n. nasuta	
4. Coorg	201.001
5. Seychelles Islands (Sy-1)	201.006
6. Kenya	201.008
D. n. albomicans	
7. Okinawa	202.001
8. Taiwan	202.002
9. Pescadores	202.003

Wolfner, 2002; Hegde *et al.*, 2000; Singh *et al.*, 2002; Ashadevi and Ramesh, 2001). Further, Hegde and Krishna (1997) have hypothesized that 'bigger is better' with reference to body size and mating success. While Ravi Ram and Ramesh (2002) have shown the existence of positive correlation between quantity of secretions and the size of the gland. Present study was undertaken to understand the relationship if any, that exists between the body size and quantity of accessory gland secretory proteins in few members of *D. nasuta* and *D. melanogaster* subgroups.

The stocks for the present study were obtained from Drosophila Stock Centre, University of Mysore, Mysore, India (Table 1). Uniformity was maintained with regard to temperature, space, amount of food, moisture and the larval population density in culture. Synchronized eggs were collected from these flies through modified method of Delcour (Ramachandra and Ranganath, 1988). 50 eggs were placed in each vial (5 cm × 2.5 cm) containing 5 ml of wheat cream agar medium seeded with yeast. All the experimental cultures were maintained at 22 ± 1°C and R.H of 69%.

Unmated males and virgin females were isolated from these cultures within 3 hrs of their eclosion from the pupal case. They were transferred to vial containing fresh media and aged for 7 days. The accessory glands from individual males were dissected and the samples were prepared (see Ravi Ram and Ramesh, 2001). The quantity of secretory proteins in these samples was estimated by micro method (Neuhoff, 1985) using BSA as the standard. In this study, we have used wing length as an index of body size. The wing from seven days old unmated flies were dissected out, placed in a horizontal plane and the length from humeral cross vein to tip of the wing (Fig. 1) was measured using a calibrated ocular micrometer.

The data were subjected to ANOVA followed by DMRT to analyze the significance of differences. Correlation coefficient was also calculated to understand the relationship between body size and male accessory gland secretory proteins.

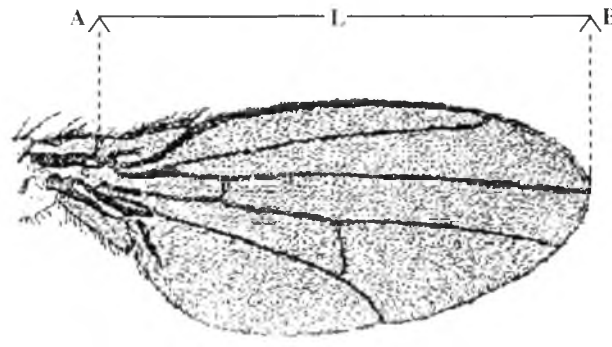


FIGURE 1. Wing of *Drosophila* (From Fly base–http://flybase.org.) A = Humeral crossvein; B = Tip of the wing; L = Wing length.

Among the three species used for the present study, *D. n. nasuta* and *D. n. albomicans* are closely related (Ranganath, 2002), while *D. melanogaster* is taxonomically unrelated to the other two. Thorax length has been used as an index of body size in *Drosophila* (see Partridge *et al.*, 1987; Santos *et al.*, 1988, 1992). Wing is another phenotypic trait that can be used as an index of body size (Sokoloff, 1966; Hegde *et al.*, 2000). Table 2 embodies data on the body size and quantity of accessory gland secretory proteins in different species/strains understudy. Perusal of the table reveals that the body size varies from a minimum of 1805 μm (*D. melanogaster*–Canton S) to a maximum of 2083 μm (*D. n. nasuta*–Coorg strain). Similarly, the quantity of accessory gland secretory proteins vary from a minimum of 5.33 μg (*D. melanogaster*–Canton S) to a maximum of 21.5 μg (*D. n. albomicans*–Okinawa). Considering the variation in body size on one hand and quantity of accessory gland proteins on the other, in a comparison among different strains of the same species, we find that in case of *D. n. nasuta* and *D. n. albomicans*, though there are marginal differences in body size, the quantity of accessory gland proteins synthesized remain same. Some interesting relationships emerge when we make interspecific comparisons. (Table 2) Though the body size of *D. melanogaster* (Oregon K) and *D. n. nasuta* (Kenya) are same; the quantity of proteins synthesized in *D. n. nasuta* is double. Similarly, though the body size of *D. n. nasuta* (Coorg) and *D. n. albomicans* (Okinawa) are similar, they differ with respect to quantity of accessory gland proteins synthesized. Same is true in comparisons between Seychelles strain of *D. n. nasuta* and Taiwan and Pescadores strains of *D. n. albomicans*, though the body size is similar. Thus, when total Acp quantity in different strains and species of *Drosophila* analyzed is considered, it is evident that they fall into 3 clusters (Fig. 2) wherein different strains of *D. melanogaster*, *D. n. nasuta* and *D. n. albomicans* form one cluster each. It is also evident that the total Acp quantity in *D. n. nasuta* is double and it is triple in *D. n. albomicans* when compared with what is prevalent in *D. melanogaster*.

Shivanna and Ramesh (1995b) have documented the absence of differences in the quantity of larval sa vary gland secretions not only between *D. n. nasuta* and *D.n.*

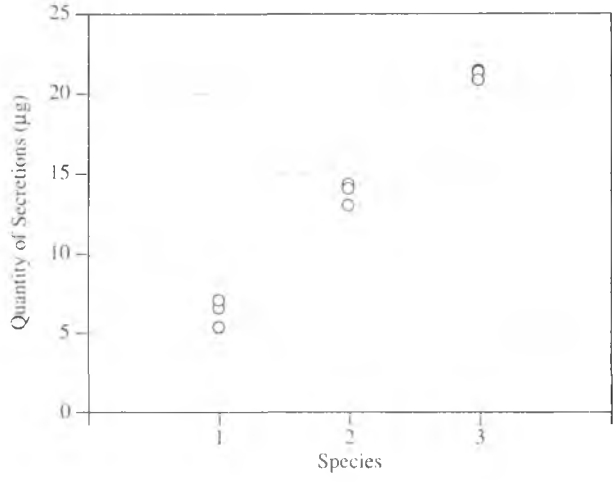


FIGURE 2. Quantity of male accessory gland secretory proteins in different strains of three species of *Drosophila*.

TABLE 2. Body size and quantity of accessory gland secretory proteins in various species/strains under study

Species/Strains	Body size (μm)	Total Acp (μg)
D. melanogaster		
1. Oregon K	1833 ± 8.98^{ce}	6.55 ± 0.39^{ce}
2. Canton S	1805 ± 7.07^{e}	5.33 ± 0.37^{de}
3. Berlin	1934 ± 12.6^{f}	7.00 ± 0.21^{c}
D. n. nasuta		
4. Coorg	2083 ± 14.04^{a}	14.25 ± 0.41^{a}
5. Seychelles Islands (Sy-1)	1994 ± 8.93^{bg}	14 ± 0.46^{a}
6. Kenya	1867 ± 6.87^{c}	13 ± 0.29^{a}
D. n. albomicans		
7. Okinawa	2042 ± 7.02^{adg}	21.5 ± 0.67^{b}
8. Taiwan	2004 ± 7.86^{bd}	21.4 ± 0.69^{b}
9. Pescadores	1996 ± 8.12^{bi}	20.9 ± 0.84^{b}
F Value	25.0	164.0

Note: $n = 25$; df = (8, 216).
The strains with same alphabet in superscript are not significantly different at 5% level according to DMRT.

albomicans but also among different species/subspecies that belong to *immigrans* group. Ravi Ram and Ramesh (2002) studied the quantity of male accessory gland secretory proteins in relation to the number of cells in the gland, size of the gland and

the copulation duration in 7 members of *D. nasuta* subgroup. Such a study revealed that the differences in the quantity of secretions are independent of number of cells in the gland and copulation duration. However, they could find correlation between size of the gland and the quantity of secretions. They proposed that the difference in Acp quantity is a consequence of differential *Acp* gene activity. Though *D. n. nasuta* and *D. n. albomicans* have open genetic system, at present we do not know the significance of increased quantity of secretions in *D. n. albomicans* alone as compared with rest of *nasuta* subgroup members. In *D. melanogaster* so far 36 Acp genes have been identified (Wolfner, 1997). It is possible that *D. melanogaster* might have basic set of *Acp* genes, the activity of all of which is required for normal reproduction; while in *D. n. nasuta*, these Acp genes may be present in duplicate and in *D. n. albomicans*, in triplicate and all these sets may be active? or the differences observed may be a consequence of differential regulation of gene expression in the basic set of genes that is species specific.

ACKNOWLEDGEMENTS

We thank The Chairman of our department for the facilities, Dr. H. A. Ranganath for valuable suggestions, Dr. K. Ravi Ram and Dr. J. S. Ashadevi for their help.

REFERENCES

Ashadevi, J. S. and Ramesh, S. R. (2001) Genetic and biochemical analysis of brown eye mutation in *Drosophila nasuta nasuta Drosophila nasuta albomicans*. *Genetica* **1709**: 1–9.

Chapman, T., Neubaum, D. M., Wolfner, M. F. and Patridge, L. (2000) The role of male accessory of gland protein ACP36DE in sperm competition in *Drosophila melanogaster*. *Proceedings of Royal Society of Biological Science* **27**: 1097–1105.

Chen, P. S. (1984) The functional morphology and biochemistry of insect male accessory glands and their secretions. *Annual Review of Entomology* **29**: 233–255.

Chen, P. S. (1996) The accessory gland proteins in male *Drosophila*: structural, reproductive and. evolutionary aspects. *Experentia* **521**: 503–510.

Gilchrist, A. S. and Partridge, L. (2001) Why it is difficult to model sperm displacement in *Drosophila melanogaster*, the relation between sperm transfer and copulation duration. *Heredity* **86**: 144–152.

Hegde, S. N. and Krishna, M. S. (1997) Size assortative mating. *Animal Behaviour* **54**: 419–426.

Hegde, S. N., Naseerulla, Krishna and M. S., (2000) Variability of morphological traits in *Drosophila*. *Indian Journal of Experimental Biology* **38**: 797–806.

Neuhoff, V. (1985) *In Modern Methods in Protein chemistry*. Tschesche, H. (Ed). Walter de Gruyter: Berlin, 1–62.

Partridge, L., Hoffman, A., Jones, A. and Jones, J. S. (1987) Male size and mating success in *Drosophila melanogaster* and *Drosophila pseudoobscura* under field conditions. *Animal Behaviour* **35**: 468–476.

Ramachandra, N. B. and Ranganath, H. A. (1988) Estimation of population fitness of the parental races and of the newly evolved cytoraces-the products of interracial hybridization. *Genome* **30**: 58–62.

Ranganath, H. A. (2002) Evolutionary Biology of *Drosophila nasuta* and *Drosophila albomicans*. *Proceedings of Indian National Science Academy (PINSA)* **B68**: 255–272.

Ravi Ram, K. and Ramesh, S. R. (1999) Ontogenetic profiles of male accessory gland secretory proteins in a few species of *nasuta* subgroup of *Drosophila*. *Drosophila Information Service* **67**: 65–67.

Ravi Ram, K. and Ramesh, S. R. (2001) Male accessory gland secretory proteins in a few members of the *Drosophila nasuta* subgroup. *Biochemical Genetics* **39**: 99–115.

Ravi Ram, K. and Ramesh, S. R. (2002) Male accessory gland secretory proteins in *nasuta* subgroup of *Drosophila*: synthetic activity of Acp. *Zoological Science* **19**: 513–518.

Ruiz, A. and Santos, M. (1989) Mating probability, body size and inversion polymorphism in a colonizing population of *Drosophila buzzatii*. In: *Evolutionary Biology of Transient Unstable Pupulations*, Fontdevila, A. (Ed). Springer Verlag: Berlin, 96–113.

Ruiz, A., Santos, M., Barbadilla, J. E., Quezada-Diaz, J. E., Hasson, E. and Fontdevilla, A. (1991) The evolutionary history of *Drosophila buzzatii* XVIII. Genetic variation for body size in a natural population. *Genetics* **128**: 739–750.

Santos, M., Ruiz, A., Barbadilla, A., Quezada-Diaz, J. E., Hasson, E. and Fontdevila, A. (1988) The evolutionary history of *Drosophila buzatii*. XIV Larger flies mate more often in nature. *Heredity* **61**: 255–262.

Santos, M., Ruiz, A., Quezada-Diaz, J. E., Barbadilla, A. and Fontdevila, A. (1992) The evolutionary positive phenotypic covariance between field adult fitness components and body size. *Journal of Evolutionary Biology* **5**: 403–422.

Shivanna, N. and Ramesh, S. R. (1995a) Quantitative and qualitative analysis of accessory gland secretory proteins in few species of *Drosophila immigrans* group. *Indian Journal of Experimental Biology* **33**: 668–672.

Shivanna, N. and Ramesh, S. R. (1995b) Increase in size of the gland is not associated with increase in secretion: an evidence from larval salivary glands of *Drosophila*. *Current Science* **68**: 1246–1249.

Singh, S. R., Singh, B. N. and Hoenigsberg, H. F. (2002) Female remating, sperm competition and sexual selection in *Drosophila*. *Genetics and Molecular Research* **1**: 178–215.

Sokoloff, A. (1966) Morphological variations in natural and experimental populations of *Drosophila pseudoobscura* and *Drosophila persimilis*. *Evolution* **20**: 49–71.

Wolfner, M. F. (1997) Tokens of love: functions and regulation of *Drosophila* male accessory gland products. *Insect Biochemical Molecular Biology* **27**: 179–192.

Wolfner, M. F. (2002) The gift that they keep on giving: physiological functions and evolutionary dynamics of male seminal proteins in *Drosophila*. *Heredity* **88**: 85–93.

(Received 29 August 2003; accepted 15 January 2004)

ENTOMON 29(1): 63–66 (2004)
Short Communication No. ent.29110

Host feeding pattern of *Coquillettidia (Coquillettidia) crassipes* (van der Wulp) from Kerala, India

P. Philip Samuel*, N. Arunachalam, J. Hiriyan and V. Thenmozhi

Centre for Research in Medical Entomology, (Indian Council of Medical Research), 4, Sarojini Street, Chinna Chokkikulam, Madurai 625002, Tamil Nadu, India
Email: crmeicmr@satyam.net.in

ABSTRACT: The host feeding patterns of *Coquillettidia crassipes* were analysed as part of studies conducted on the vectors of JE and filariasis in the Kuttanadu region of Kerala State. Blood-fed *Cq. crassipes* female mosquitoes were collected from outdoor resting habitats by using hand catch method during dusk hour and also by using drop-net method. A total of 28 blood-fed *Cq. crassipes* were smeared and agarose gel diffusion method was used to identify blood meals from these mosquitoes. Sera were tested against the anti-sera to cow, pig, duck, goat, fowl and human. Results revealed that *Cq. crassipes* is an ornithophilic mosquito since 46.3% (fowls 32%, ducks 14.3%) of the *Cq. crassipes* had fed on birds. Only one specimen had fed on cattle. The blood meals of half of the *Cq. crassipes* mosquitoes collected remains unknown. *Coquillettidia crassipes* may play a role as enzootic vectors in the maintenance of arthropod-borne viruses during inter-epidemic period in an enzootic cycle involving birds as amplifying hosts. © 2004 Association for Advancement of Entomology

KEYWORDS: *Coquillettidia crassipes*, blood meal, ornithophilic

The knowledge of mosquito host relationship is very important to understand the epidemiology of mosquito-borne diseases of man and animals for which these insects serve as vectors (Hess *et al.*, 1968). Thus, identification of blood-meals in haematophagous arthropods is an important tool in epidemiological investigation of vector-borne diseases (Savage *et al.*, 1991).

The subperiodic strains of *Brugia malayi* is also transmitted by *Cq. crassipes* in South Asia (White, 1989). The blood meals of *Cq. crassipes* were analyzed, as only very few reports are available on the feeding pattern of *Cq. crassipes*, one of the vectors of sub-periodic form of Brugian filariasis (White, 1989). *Coquillettidia crassipes* is distributed in India, Sri Lanka, China, Ryukyu Islands and the Philippines and New Guinea, Australia and the South Pacific Islands (Darsie and Pradan, 1990). In India, *Cq. crassipes* is common in the Punjab and eastwards to Assam (Barraud, 1934) and found breeding in permanent and semi-permanent ponds containing aquatic plants

*Corresponding author

© 2004 Association for Advancement of Entomology

such as *Pistia* and *Eicchornia* from which they obtain air for respiration by inserting the modified siphons into submerged roots and stems (Tanaka *et al.*, 1979).

The present study was carried out from June 1998 to January 2001 in Kuttanadu region of Kerala, which forms the interface of marine, estuarine and fluvial systems representing a highly complex ecosystem. Most of the area is lying below mean sea level and remain waterlogged for most part of the year.

Coquillettidia crassipes could be collected from outdoor resting places in very low numbers, which formed only 1.05% (109 numbers) of the total mosquitoes collected in the dusk collections. But *Culex tritaeniorhynchus* (66.9%) the major vector of Japanese encephalitis, *Mansonia annulifera* (3%), *Mansonia indiana* (8%), and *Mansonia uniformis* (9.6%) the vectors of filariasis were collected in good numbers in the dusk collections (Arunachalam *et al.*, 2004). Fully engorged mosquitoes were collected from vegetation and bushes by using drop- net method (De Zulueta, 1950). Similarly in addition to the major vectors of Japanese encephalitis and filariasis, blood-fed *Cq. crassipes* females were also collected, though in few numbers, from outdoor resting habitats only. Stomach contents of 28 blood-fed *Cq. crassipes* were smeared on Whatman No.1 filter paper strips, dried, and stored at 4 °C.

The agarose gel diffusion method (Collins *et al.*, 1986) with minor modifications as described by Reuben *et al.* (1992), was used to identify blood-meal source. Anti-sera to cow, pig, duck, goat, fowl and human were procured from the Serologist, Government of India, Kolkata, India and used for the tests.

Outdoor resting habit of *Cq. crassipes* showed its exophillic and exophagic behaviour. The results of the precipitin tests revealed that *Cq. crassipes* is ornithophilic in nature since 46.3% of them had fed on birds (fowls 32%, ducks 14.3%) which were mainly reared in the backyard of many houses. Of the total collections only one specimen was found fed on cattle. Thus *Cq. crassipes* showed a preference for avian rather mammalian hosts as also seen in *Cq. perturbans* (Murphy *et al.*, 1967). Another 50% (14 numbers) could not be identified with all the 6 antisera tested and remains unknown.

In Paupua New Guinea, only 3 numbers *Cq. crassipes* were collected which showed bird and dog feeding (van den Hurk *et al.*, 2003). Thus in other places also the density of these mosquitoes were very less compared to what was recorded here. Similarly, Edman (1971) identified blood meals of *Cq. perturbans* as avian and mammalian blood. *Coquillettidia perturbans* (Walker) was implicated as a bridge vector for Eastern Equine Encephalomyelitis virus in North America for the transmission from the bird/*Culiseta melanura (Coquillett)* cycle to susceptible dead-end hosts like horses and exotic birds such as emu and pheasant (Bosak *et al.*, 2001). This study also revealed the ornithophilic behaviour of *Cq. crassipes*. Japanese encephalitis is a zoonotic disease, prevalent in this area and the life cycle of JE virus involves the birds as the maintenance host. Hence, *Cq. crassipes*, ornithophilic species of mosquitoes may play a role as enzootic vectors in the maintenance of arthropod-borne viruses during inter-epidemic period in an enzootic cycle involving birds as amplifying hosts (Sardelis *et al.*, 2001). Since less number of *Cq. crassipes* were collected, virus

isolations could not be attempted. However, JE virus was isolated from *Mansonia* mosquitoes, which are considered as 'bridge vectors' in JE virus transmission in the same study area (Arunachalam *et al.*, 2002). Along with *Mansonia* species, *Cq. crassipes* may also play a role as bridge vectors because of its high ornithophilic feeding habit. Further more work is to be carried out on this particular species of mosquitoes to validate the role of *Cq. crassipes* in JE virus transmission.

ACKNOWLEDGEMENTS

The authors are grateful to SEARO/WHO New Delhi for financial support. This publication is an outcome from the WHO project (SN 1094). We thank the staff Mr. A. Veerapathiran, Mr. V. Kodangi Alagan and Mr. V. Rajamannar of Vector Biology and training division of Centre for Research in Medical Entomology for excellent technical assistance. We appreciate the excellent help rendered by Shri A. Venkatesh, Research Assistant, CRME, Madurai, in preparation of this manuscript, particularly in DTP work.

REFERENCES

Arunachalam, N., Philip Samuel, P., Hiriyan, J., Thenmozhi, V., Balasubramanian, A., Gajanana, A. and Satyanarayana, K. (2002) Vertical transmission of Japanese encephalitis virus in *Mansonia* species, in an epidemic-prone area of southern India. *Ann. Trop. Med. Parasitol.* **96(3)**: 1–2.

Arunachalam, N., Philip Samuel, P., Hiriyan, J., Thenmozhi, V. and Gajanana, A. (2004) Japanese encephalitis in Kerala, South India: role of Mansonia (Diptera: Culicidae) in transmission of Japanese encephalitis virus. *J. Med. Entomol.* **41**: 456–461.

Barraud, P. J. (1934) *The Fauna of British India Including Ceylon and Burma*, Diptera Vol. V Family Culicidae. Today & Tomorrow's Printers & Publishers: New Delhi.

Bosak, P. J., Reed, L. M. and Crans, W. J. (2001) Habitat preference of host-seeking *Coquillettidia perturbans* (Walker) in relation to birds and eastern equine encephalomyelitis virus in New Jersey. *J. Vector Ecol.* **26(1)**: 103–109.

Collins, R. T., Dash, B. K., Agarwala, R. S. and Dhal, K. B. (1986) An adaptation of the gel diffusion technique for identifying the source of mosquito blood meals. *Indian J. Malariol.* **23**: 81–89.

Darsie, R. F. and Pradan, S. P. (1990) The mosquitoes of Nepal: their identification, distribution and biology. *Mosq. System.* **22**: 70–130.

De Zulueta, J. (1950) A study of the habits of the adult mosquitoes dwelling in the savanna of eastern Colombia. *Am. J. Trop. Med. Parasitol.* **30**: 325–339.

Edman, J. D. (1971) Host-seeking patterns of Florida mosquitoes, 1 *Aedes, Anopheles, Coquillettidia, Mansonia* and *Psorophora*.. *J. Med. Entomol.* **8**: 687–695.

Hess, A. D., Richard, O. H. and Tempelis, C. H. (1968) The use of forage ratio techniques in mosquito host preference studies. *Mosquito News* **28**: 386–389.

Murphy, F. J., Burbutis, P. P. and Bray, D. F. (1967) Bionomics of *Culex salinarius Coquillett*. II. Host acceptance and feeding by adult females of *Cx. salinarius* and other mosquito species. *Mosq. News.* **27**: 366–374.

Reuben, R., Thenmozhi, V., Philip Samuel, P., Gajanana, A. and Mani, T. R. (1992) Mosquito blood feeding patterns as a factor in the epidemiology of Japanese encephalitis in Southern India. *Am. J. Trop. Med. Hyg.* **46**: 654–663.

Sardelis, M. R., Turell, M. J., Dohm, D. J. and O'Guinn, M. L. (2001) Vector competence of selected North American Culex and Coquillettidia mosquitoes for West Nile virus. *Emer. Infect. Dis.* **7**: 1018–1022.

Savage, H. M., Duncan, J. F., Roberts, D. R. and Sholdt, L. L. (1991) A dipstick ELISA for rapid detection of human blood meals in mosquitoes. *J. Amer. Mosq. Contr. Assoc.* **7**: 16–23.

Tanaka, K., Mizusawa, K. and Saugstad, E. S. (1979) A revision of the adult and larval mosquitoes of Japan (including the Ryukyu Archipelago and the Ogasawara Islands) and Korea Diptera: Culicidae). *Cont. Amer. Entomol. Inst.* **16**.

van den Hurk, F., Johansen, C. A., Zborowski, P., Paru, R., Foley, P. N., Beebe, N. W., Mackenzie, J. S. and Ritchie, S. A. (2003) Mosquito host-feeding patterns and implications for Japanese encephalitis virus transmission in northern Australia and Papua New Guinea. *Med. Vet. Entomol.* **17**: 403–411.

White, G. B. (1989) Geographical distribution of arthropod-borne diseases and their principal vectors WHO vector Biology Division.

(Received 6 August 2003; accepted 9 February 2004)

ENTOMON **29(1)**: 67–68 (2004)
Short Communication No. ent.29111

Host resistance in guava fruit fly *Bactrocera correcta* Bezzi management

S. Mohamed Jalaluddin*[1], H. Usha Nandhini Devi[1] and K. Natarajan[2]

[1]*Sugarcane Research Station, Sirugamani, Tiruchy District 639115, India*
[2]*Department of Agricultural Entomology, Coimbatore, India*

ABSTRACT: Nine guava cultivars, *Psidium guajava* L. were screened against the fruit fly, *Bactrocera correcta* Bezzi. The cultivar Lucknow–46 was classified as very resistant and Chittidar as highly susceptible. © 2004 Association for Advancement of Entomology

KEYWORDS: *Bactrocera correcta*, *Psidium guajava*, resistance screening, Lucknow – 46

Guava fruits are damaged by a variety of insect species. Among them, fruit flies cause major havoc to the crop, reducing both quality and quantity of fruits. The principal species that attack guava fruit include*Bactrocera correcta*, *B. zonata*. *B. dorsalis*, and *B. diversa*. Of these, *B. correcta* is common in Tamil Nadu and the yield loss varies from 60–90%. Insecticidal treatment to control the fruit flies is discouraged due to the serious health hazards and mammalian toxicity. Alternative methods for fruit fly control include the use of attractant traps (Steiner, 1965; Tan, 1985), habitat manipulation and orchard design (Ahuja, 1994), use of plant growth regulators (Greany, 1994), growing of insect resistant cultivars (Rana *et al.*, 1990) and use of insecticides of plant origin (Stark *et al.*, 1990). The present study was undertaken to assess the scope of host plant resistance in integrated pest management for *B. correcta*.

The screening of nine guava cultivars for resistance to guava fruit fly *B. correcta* was carried gut in a guava orchard of Anbil Dharmalingam Agricultural College Research Institute, Thiruchirappalli for three seasons during 1994 and 1995 with all regular agronomic practices and under insecticide free environment. In every picking, 50 fruits collected from all directions and at different heights of a tree constituted one replication. Three such replications were maintained and per cent fruit damage was worked out every fortnight . The experiment was conducted in completely randomized design and the data were transformed into arc sine values for statistical analysis.

Screening was carried out in the kharif season which coincided with the peak activity of fruit fly. The first screening was conducted during 1994 where the per

*Corresponding author

© 2004 Association for Advancement of Entomology

TABLE 1. Mean per cent fruit damage in different guava cultivars

Cultivar	Mean per cent fruit damage (Values given are arcsine transformed)		
	Kharif 1994	Kharif 1995	Mean
A.C.10	3.09	27.81	15.45
Allahabad	29.75	38.70	34.23
Anakapalli	28.30	32.72	30.51
Bangalore round	3.66	35.63	19.65
Bapatla	27.46	31.73	29.60
Chittidar	40.87	62.13	51.50
Hafsi	4.92	35.25	40.17
Lucknow – 46	0.57	0.57	0.57
Lucknow - 49	3.09	52.48	27.79
SE (±)	1.94	4.17	3.06
CD at 5%	4.04	8.84	6.44

cent damage in the cultivars ranged from 0.57 to 40.87 per cent. Second screening was conducted during kharif 1995 where the per cent fruit damage in the cultivars ranged from 0.57 to 62.13 per cent (Table 1) The fruit fly population was generally high during the second year, i.e. Kharif 1995, causing greater damage. In both seasons, Lucknow-46 cultivar scored consistently less damage and chittidar scored the maximum (62.13%) damage.

Although, some other cultivars (A.C.10, Bangalore Round, Hafsi and Lucknow 49) also scored comparatively lower damage during the first year, they suffered higher damage in the second year. The performance of the least susceptible Lucknow - 46 and the highly susceptible Chittidar was consistent in both the years. Further studies are suggested to confirm these findings.

REFERENCES

Ahuja, M. (1994) Future trends in fruit fly management. In: *4th International Symposium on Fruit Flies of Economic Importance*, (June 5–10. Sandkey, Florida, x–1) Abstracts.

Greany, P. (1994) Gibberellic acid is a potent, biorational new tool for the management of fruit flies. In: *4th International Symposium on Fruit Flies of Economic Importance*, (June 5–10. Sand Key, Florida), 4–2) Abstracts.

Rana, J. S., Prakash, O. M. and Verma, S. K. (1990) A note on relative susceptibility of some guava cultivars to fruit fly *Dacus zonatus* (Saunders). *Haryana J. Hort. Sci.* **19**: 131–133.

Stark, J. D., Vargas, R. I. and Thalman, R. K. (1990) Azadirachtin: effects on metamorphosis, longevity and reproduction of three tephritid fruit fly species (Diptera: Tephritidae). *J. Econ. Entomol.* **83**: 2168–2178.

Steiner, L. F. (1965) Oriental fruit fly eradication by male annihilation. *J. Econ. Entomol.* 961–964.

Tan, K. H. (1985) Estimation of native population of male *Dacus* spp By Jolly's stochastic model using a new designed attractant trap in a village ecosystem. *J. Plant Prot. Tropics* **2**: 87–95.

(Received 18 September 2002; accepted 30 January 2004)

ENTOMON 29(1): 69–73 (2004)
Short Communication No. ent.29112

Further studies on two Indian species of subgenus *Lutzia* Theobald of genus *Culex* Linnaeus (Diptera: Culicidae)

J. S. Kirti* and J. Kaur

Department of Zoology, Punjabi University, Patiala 147002, India

ABSTRACT: Female genitalic structures of two species of subgenus *Lutzia* Theobald of genus *Culex* Linnaeus, *viz*, *Culex (Lutzia) fuscanus* Wiedemann and *Culex (Lutzia) halifaxii* Theobald have been described and illustrated.
© 2004 Association for Advancement of Entomology

KEYWORDS: Indian species, subgenus *Lutzia*, genus *Culex*

Collection cum survey tours were conducted in different localities of North-West India to study the mosquito fauna. As many as 57 species referable to various genera were identified and studied for different morphological attributes including external genitalia. Out of these two species belonging to subgenus *Lutzia* Theobald of genus *Culex* Linnaeus were identified as *L. fuscanus* Wiedemann and *L. halifaxii* Theobald with the help of keys given by Barraud (1934) and by comparison from museum of Zoological Survey of India, Kolkata. Keeping in view the taxonomic significance of the genitalic attributes, the authors have made detailed observations on the structure of female genitalia in the present communication for the first time. Descriptions of the male genitalia of these two species is already known. The terminology for naming constituent parts of the female genitalia was followed from Hara (1957, 1959) and Harbach and Knight (1980).

The species under study were collected from various state of North-West India using the suction-tube method. Larval and pupal collections were made from coolers, tree holes, domestic containers and ponds and pools in both forests and plain areas using a dropper. These were reared in field laboratory until adult emergence. Adults were killed with ethyl acetate vapours before being pinned and preserved in air tight insect cabinets. For the removal of female genitalia, the last two segments of the abdomen were snipped off with fine forceps. These abdominal tips were placed in 10% KOH solution and were boiled for 2–3 minutes, the unwanted parts were then removed, potashed material was properly dehydrated and cleared in clove oil. These genitalic

*Corresponding author

© 2004 Association for Advancement of Entomology

structures were then transferred in mounting medium on glass slide and covered by cover slip. Drawings were made with the help of a graph eye piece under binocular at different magnifications.

Subgenus *Lutzia* theobald

Theobald, 1903, *Monog. Culic*, 3: 155.

Type species

Lutzia bigoti Theobald.

Distribution

Africa; Central and South America; Oriental region.

***Culex (Lutzia) fuscanus* Wiedemann (Figs 1–4)**

Wiedemann, 1821, *Dipt. Exot.* **1**: 9.

Female genitalia

Cerci short and plumpy; postgenital plate conical with rounded apex, setosed with 16 long setae and numerous microsetae; tergum IX band like, bearing 2 submedian groups of 6–8 setae; sigma membranous; cowl with chitinous margin; spermatothecal eminence indistinct; horse shoe structure not swollen medially; insula setosed with a group of 16 setae; 3 spermatothecae present.

Material examined

Punjab: Patiala, 6.X.1997, 1♂, 21.XII.1997, 1♂ 8.XI.1998, 3♀♀, 4♂♂.

Old distribution

India: North West and North East India.

***Culex (Lutzia) halifaxii* Theobald (Figs 5–8)**

Theobald, 1903, *Mon. Cul.*, **3**: 231.

Female genitalia

Cerci plumpy, somewhat swollen apically; postgenital lobe tongue like with rounded tip, setosed with 6 pairs of setae pointing caudally apart from few setae of moderate size and numerous microsetae; tergum IX band like bearing submedian group of 7–8 minute setae on either side of mid line; insula with a group of 16 long setae; sigma membranous; cowl well sclerotized; atrial plate present; horse shoe structure swollen at many points throughout length; 3 spermatothecae present.

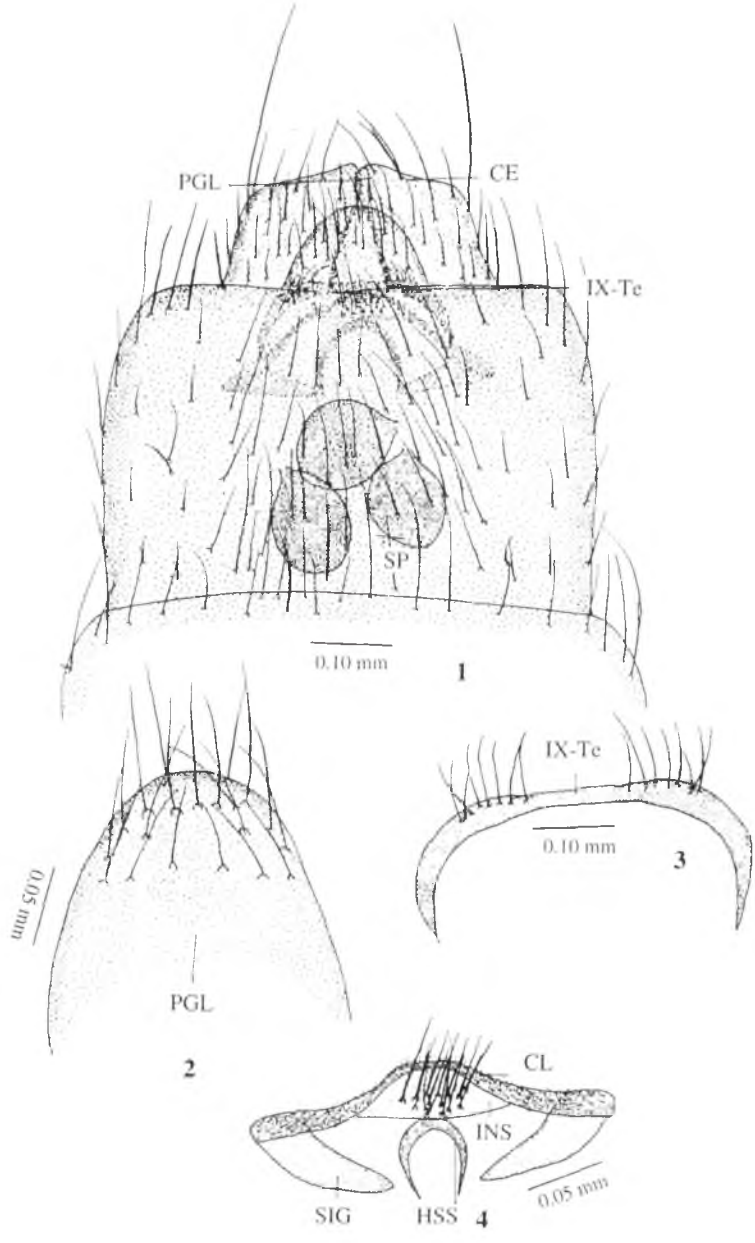


Figure 1–4. *Culex (Lutzia) fuscanus* Wiedemann: 1. Female genitalia; 2. Postgential lobe; 3. Tergum-IX; 4. Terminalia.

Abbreviations

CL	–	cowl	CE	–	Cercus	SP	–	Spermatotheca
INS	–	Insula	HSS	–	Horse shoe structure	IX-Te	–	Tergum IX
PGL	–	Postgenital lobe	SIG	–	Sigma			

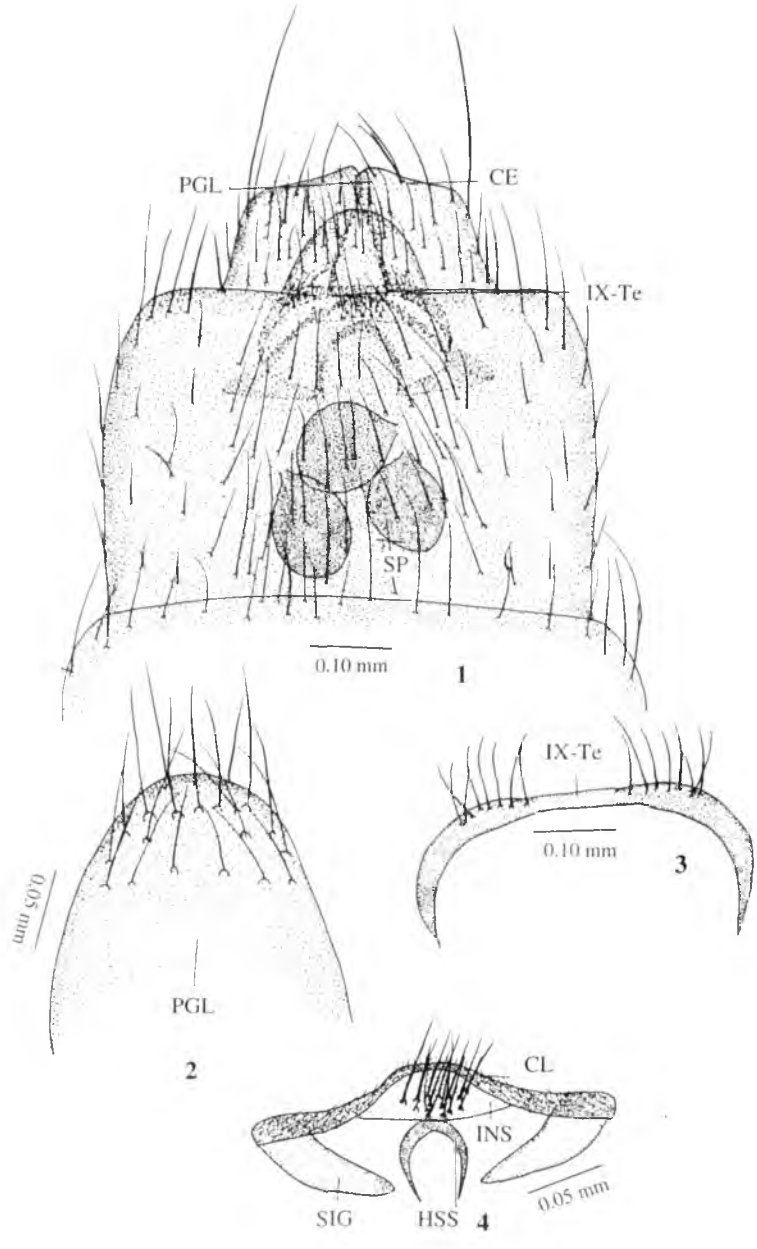


Figure 5–8. *Culex (Lutzia) halifaxii* Theobald: 5. Female genitalia; 6. Postgential lobe; 7. Tergum-IX; 8. Terminalia.

Material examined

Uttaranchal: Dehradun, Sodhiwal, 12.VII.1999, 1♀, 1♂, Mussoorie (2150 mts), 13.VII.1999, 4♀♀, 4♂♂.

Old distribution

India: Assam, Himachal Pradesh, Nilgiri Hills, Uttaranchal. Outside India: Hongkong; Japan.

ACKNOWLEDGEMENTS

Thanks are due to the Director, Malaria Research Centre, New Delhi and Director, National Institute of Communicable Diseases, New Delhi for providing relevant literature and other facilities.

REFERENCES

Barraud, P. J. (1934) *Fauna of British India Including Ceylon and Burma*. Taylor and Francis Ltd.: London, 1–463.

Hara, J. (1957) Studies on the female terminalia of Japanese mosquitoes. *Japan J. Exp. Med.* **27**: 45–91.

Hara, J. (1959) Taxonomical notes on the female terminalia of some Anopheline mosquitoes of Japan of Formosa. *Japan. J. Exp. Med.* **29(2)**: 107–109.

Harbach, R. E. and Knight, K. L. (1980) *Taxonomists Glossary of Mosquito Anatomy*, Plekus Maslton: New Jersey.

(Received 5 July 2003; accepted 25 March 2004)

ENTOMON 29(1): 75–80 (2004)
Short Communication No. ent.29113

Susceptibility of the American Bollworm, *Helicoverpa armigera* (Hübner) from cotton ecosystem to *Bacillus thuringiensis* Berliner var. *kurstaki* HD-1

G. T. Gujar*, Archana Kumari and V. Kalia

Division of Entomology, Indian Agricultural Research Institute, New Delhi 110012, India
Email: gtgujar@iari.res.in

ABSTRACT: The susceptibility of neonate larvae of the American bollworm, *Helicoverpa armigera* collected from different localities in north India to *Bacillus thuringiensis* var. *kurstaki* HD-1, in September 2001 ranged about four-fold (LC_{50} 96 h from 127.5–546.4 μg endotoxin l^{-1} diet) for cotton ecosystem. The LC_{90} of *B. thuringiensis* var. *kurstaki* HD-1 for different populations ranged from about 951 to 13, 125 μg endotoxin l^{-1} diet, with a mean of about 5,200 μg endotoxin l^{-1} diet. The narrow range of variation in susceptibility could be due to limited genetic variation of *H. armigera* in cotton ecosystem. These results could be used as baseline standards for monitoring *H. armigera* resistance to *B. thuringiensis* var. *kurstaki* HD-1 for cotton ecosystem. © 2004 Association for Advancement of Entomology

KEYWORDS: American bollworm, *Helicoverpa armigera* (Hübner), *Bacillus thuringiensis* Berliner var. *kurstaki* HD-1, baseline susceptibility

The American bollworm, *Helicoverpa armigera* (Hübner) is the most important pest of cotton in India and elsewhere. It infests leaves, flowers and bolls, especially bolls. It causes direct significant loss of cotton productivity requiring control measures in as many as 24 countries (Ridgeway *et al.*, 1984). In view of economic importance of cotton, about 50 per cent of insecticide usage is directed for the control of bollworms, especially *H. armigera*. However, the insect pest has developed resistance to almost all kinds of insecticides (McCaffery, 1999).

Bacillus thuringiensis is a soil inhabiting, spore-forming, Gram positive bacterium pathogenic to insects. It is highly safe to the environment (Entwistle *et al.*, 1993). Hence, it is widely used for the control of insect pests of agriculture, forestry and public health. There are more than 63 different serovars of *B. thuringiensis* (Thiery and Frachon, 1997). *B. thuringiensis* var. *kurstaki* HD-1 is the most widely used strain

*Corresponding author

© 2004 Association for Advancement of Entomology

for control of lepidopteran insects and is recommended for the integrated management of *H. armigera* (Butter *et al.*, 1995; Puri *et al.*, 1998; Gujar *et al.*, 2000b). In India, the usage of *B. thuringiensis* has increased from about 30 in the early 1990s to about 120 tons annum^{-1} at present. About a dozen *B. thuringiensis* products like Bioasp®, Biobit®, Biolep®, Dipel®, Halt® are being used for the control of lepidopteran insects, especially *H. armigera* and the diamondback moth, *Plutella xylostella*. Besides, plant incorporated protectants like *B. thuringiensis* transgenic crops are developed, especially using *B. thuringiensis* genes like *cry1Ab and cry1Ac*. *B. thuringiensis* transgenic-cum-herbicide tolerant cotton was cultivated on 4.6 million hectares area globally in 2002 (James, 2002).

One of the ecological implications of extensive use of *B. thuringiensis* as a conventional insecticide or through transgenic technology is the development of resistance in insects. *P. xylostella* has already developed resistance to *B. thuringiensis* under field conditions in many countries (Gujar and Mohan, 2002; Mohan and Gujar, 2002). Similarly, it is suspected that *H. armigera* may also develop resistance to *B. thuringiensis*. Gujar *et al.* (2000a) reported a wide range of variation in the susceptibility of *H. armigera* collected from different localities in the country to the discriminating concentrations of *B. thuringiensis* var. *kurstaki* HD-1 and HD-73. This paper describes, therefore, variation in susceptibility to *B. thuringiensis* var. *kurstaki* HD-1 of *H. armigera* populations collected from the cotton ecosystem of the North India.

Larvae of *H. armigera* were collected from cotton fields from different locations, Sirsa (29 32 N, 75 07E) in Haryana; Abohar's suburbs including Kalatibba and Chakkatibba (30 18N, 74 22E) and Bathinda (30 12N, 74 57E) in Punjab and Ganganagar (29 49N, 73 50E) in Rajasthan in September–October, 2001. The larvae were collected from farmers fields heavily treated with insecticides in view of unusually high infestation on cotton in the year 2001. The larvae mostly in the last instar stage were fed on cotton until pupation in the laboratory.

The adults emerging from pupae were offered 10 per cent honey solution fortified with multivitamins throughout their egg-laying period. Five pairs of adults were kept in each jar. The eggs laid on the cotton cloth were kept in separate jar at 27 °C moistened with water. The neonate larvae on egg hatching were considered belonging to F_1 generation and were used for bioassays.

Acetone powder of spore and crystal complex of *B. thuringiensis* var. *kurstaki* HD-1 (4D4) originally received as a gift from *Bacillus* Genetic Stock Center, OSU, Columbus, USA, was prepared using procedure described by Dulmage *et al.* (1970). The endotoxin in the acetone powder was separated on discontinuous sodium dodecyl sulphate-polyacrylamide gel electrophoresis with 8 per cent resolving gel, using Genei Mini Dual electrophoresis model (Laemmli, 1970) and identified by comparing with known protein molecular weight markers. Quantification was done by eluting Coomassie Brilliant Blue R-250 dye from band with bovine serum albumin as a standard as described by Ball (1986). The endotoxin and spore counts

of *B. thuringiensis* var. *kurstaki* HD-1 preparation were found as 124.34 μg and 89.3×10^{10} 100 mg^{-1}, respectively.

Chickpea-based meridic diet used for bioassays was essentially that of Nagarkatti and Prakaash (1974), with some minor modifications. Bioassays were carried out by diet incorporation method as per Gujar *et al.* (2000a) using acetone powder of spore-crystal complex of *B. thuringiensis* var. *kurstaki* HD-1. A series of different amounts of stock solution of acetone powder (in water) was added to an aliquot of warm diet (40 °C) before cooling, mixed thoroughly, and poured into small Petriplates. An aliquot of about 1 cm^3 was placed in a plastic container which served as one replication. About six concentrations were used for each bioassay, with at least five replications per concentration. The neonate larvae, ten, were released on treated diet per replication. The control consisted of normal meridic diet (without toxin). A minimum of 350 neonate larvae was used for each bioassay. The mortality was then pooled for each concentration. The concentrations showing corrected mortality between 20 and 80 per cent at 96 h were used for calculation of median lethal concentrations (LC_{50}). The experiments with mortality of above 10 per cent in control were discarded and repeated. All bioassays were carried out at 27 °C and 60–80 per cent RH unless stated otherwise.

The mortality data were analyzed by using maximum likelihood programme (Ross, 1977). LC_{50} were expressed in terms of μg endotoxin l^{-1} diet for 96 h period of bioassay.

The variation in susceptibility of neonate larvae of *H. armigera* from cotton ecosystem to HD-1 was about four-fold with LC_{50} ranging from 127.5 to 546.4 μg endotoxin l^{-1} diet. The LC_{90} of *B. thuringiensis* var. *kurstaki* HD-1 for different populations ranged from about 951 to 13 125 μg endotoxin l^{-1}diet, with a mean of about 5,200 μg endotoxin l^{-1} diet (Table 1).

Studies carried out on baseline susceptibility to *B. thuringiensis* var. *kurstaki* HD-1 of *H. armigera* showed a wide variation in insect response (Gujar *et al.*, 2000a). Chandrashekar *et al.* (2003) reported 14-fold variation (LC_{50} 35–494 μg/l diet incorporation four-day assay) in susceptibility of *H. armigera* populations collected from various five localities in the country to *B. thuringiensis* var. *kurstaki* HD-1. Fakrudin *et al.* (2003) reported eight-fold variation (LC_{50} 0.147–1.044 μg/ml cotton leaf-dip six-day assay) in susceptibility of twelve *H. armigera* populations from the South India to Cry1Ac. However, Kranthi *et al.* (2001) showed 67-fold variation (LC_{50} 0.01–0.67 μg/ml diet five-day assay) in susceptibility of *H. armigera* from nine-localities in the country to Cry1Ac. Wu *et al.* (1999) reported about 100-fold variation in susceptibility of *H. armigera* from five ecological cotton areas in China to Cry1Ac. Interestingly, further studies on monitoring of insect susceptibility to Cry1Ac carried out for the populations sampled mostly from *B. thuringiensis* cotton fields by Wu *et al.* (2002) found only five-fold variation in IC_{50} (a concentration producing 50 per cent inhibition of larval development to third instar; with IC_{50}ranging from 0.020–0.105 μg/ml, 0.016–0.099 μg/ml and 0.016–0.080 μg/ml for 1998, 1999 and 2000 insect populations, respectively). The possibility of Cry1Ac resistant larvae of

TABLE 1. Susceptibility of *H. armigera* to endotoxin of *B. thuringiensis* var. *kurstaki* HD-1

Place of collection	Date of collection	Date of bioassay	LC_{50} (96 h) μg endotoxin l^{-1} diet	Fiducial limits (95%)		LC_{90} (96 h) μg endotoxin l^{-1} diet	Slope ± S.E.
				Lower	Higher		
Sirsa1	Sept 5, 2001	Sept 26, 2001	289.20	192.4	542.2	2 694.34	1.32 ± 0.38
Sirsa2	Sept 7, 2001	Sept 28, 2001	416.08	256.3	1749.2	13 124.74	0.85 ± 0.28
Kalatibba	Sept 4, 2001	Sept 26, 2001	546.36	346.5	2004.9	8 735.26	1.06 ± 0.32
Chakkatibba	Sept 4, 2001	Oct 1, 2001	212.60	130.9	339.5	2 095.34	1.28 ± 0.36
Bhatinda	Sept 19, 2001	Oct 10, 2001	135.84	92.5	177.6	950.96	1.51 ± 0.28
Ganganagar	Sept 18, 2001	Nov 11, 2001	127.51	24.0	222.8	3,587.59	0.88 ± 0.33

H. armigera developing cross resistance to *B. thuringiensis* var. *kurstaki* HD-1 appears to be remote, in view of report of Akhurst and Liao (1996) who found only five-fold cross resistance of the Cry1Ac-selected 188-fold resistant larvae of *H. armigera* to Dipel®, a commercial formulation similar to *B. thuringiensis* var. *kurstaki* HD-1 that contains Cry1Aa, Cry1Ab, Cry1Ac, Cry2A and Cry2B. It is thus likely that introduction of Cry1Ac transgenic cotton in India from 2002 may not significantly affect the susceptibility of *H. armigera* towards *B. thuringiensis* var. *kurstaki* HD-1 based formulations.

Dhawan and Simwat (1998) reported higher susceptibility of larvae of *H. armigera* collected from Bhatinda than from Ludhiana to the cotton leaves treated with equivalent concentration of 1.5 kg/ha of Dipel 8 L (*B. thuringiensis* var. *kurstaki*, a commercial formulation). The results of the present studies showed a narrow variation in susceptibility to *B. thuringiensis* var. *kurstaki* HD-1 of *H. armigera*, in contrast to results of the studies on populations collected from many localities in the country. In view of heavy infestation of *H. armigera* on cotton in 2001, the conventional insecticides were extensively used thereby eliminating any variation in their influence on the susceptibility of insects to *B. thuringiensis* var. *kurstaki* HD-1. Further, low variability in insect susceptibility may be due to less genetic differences of the insect populations in the cotton ecosystem of the North India. It is suggested that a mean LC_{90} of about 5,200 (or LC_{95} 6,793 or LC_{99} 27,064) μg endotoxin l^{-1} diet for 96 h assay period could be used as a discriminating concentration for rapid monitoring of resistance in the field populations of *H. armigera* to *B. thuringiensis* var. *kurstaki* HD-1.

ACKNOWLEDGEMENT

GTG is grateful to Indian Council of Agricultural Research, New Delhi, NATP and Indian Agricultural Research Institute, Division of Entomology for funding and providing necessary infrastructure facilities.

REFERENCES

Akhurst, R. and Liao, C. (1996) Protecting an investment-managing resistance development to transgenic cotton by *Helicoverpa armigera*. In: *Proceedings of the Eighth Australian Cotton Conference*, Broadbeach, Queensland, Australian Cotton Growers Research Association: Brisbane, 299–305.

Ball, E. H. (1986) Quantification of proteins by elution of Coomassie Brilliant Blue R from stained bands after sodium dodecyl sulfate polyacrylamide gel electrophoresis. *Anal. Biochem.* **155**: 23–27.

Butter, N. S., Battu, G. S., Kular, J. S., Singh, T. H. and Brar, J. S. (1995) Integrated use of *Bacillus thuringiensis* Berliner with some insecticides for the management of bollworms on cotton. *J. Ent. Res.* **19**: 255–263.

Chandrashekar, K., Archana kumari., Kalia, V. and Gujar, G. T. (2003) Base-line susceptibility and development of tolerance in the American bollworm, *Helicoverpa armigera* (Hübner) to *Bacillus thuringiensis* Berl. var. *kurstaki* and its endotoxins in India, Pest Management Science (revision under consideration).

Dhawan, A. K. and Simwat, G. S. (1998) Evaluation of different biopesticides against cotton bollworm *Helicoverpa armigera* (Hubner). In: *Ecological Agriculture and Sustainable Development*. Dhaliwal, G. S., Randhawa, N. S., Arora, R. and Dhawan, A. K. (Eds). Indian Ecological Society: Ludhiana and CRRID, Chandigarh, Proc. Int. Conf. Ecological Agriculture and Sustainable Development, Nov 15–17, 1997 Chandigarh. **2**: 274–280.

Dulmage, H. T., Correa, J. A. and Martinez, A. J. (1970) Co-precipitation with lactose as a means of recovering the spore-crystal complex of *Bacillus thuringiensis*. *J. Invertebr. Pathol.* **15**: 15–20.

Entwistle, P., Bailey, M. J., Cory, J. and Higgs, S. (1993) *Bacillus thuringiensis: an Environmental Pesticide, Theory and Practice*, Wiley and Sons: New York.

Fakrudin, B., Badari Prasad, P. R., Prakash, S. H., KrishnaReddy, K. B., Patil, B. V. and Kuruvinashetti, M. S. (2003) Baseline resistance to Cry1Ac toxin in cotton bollworm, *Helicoverpa armigera* (Hubner) in South Indian Cotton ecosystem. *Curr. Sci.* **84**: 1304–1307.

Gujar, G. T., Archana Kumari, Kalia, V. and Chandrashekar, K. (2000a) Spatial and temporal variation in susceptibility of American bollworm, *Helicoverpa armigera* (Hübner) to *Bacillus thuringiensis* var. *kurstaki*. *Curr. Sci.* **78**: 995–1001.

Gujar, G. T., Kalia, V. and Archana Kumari (2000b) Bioactivity of *Bacillus thuringiensis* against the American bollworm, *Helicoverpa armigera* Hübner. *Ann. Plant Prot. Sci.* **8**: 125–131.

Gujar, G. T. and Mohan, M. (2002) Diamondback moth resistance to *Bacillus thuringiensis* and its toxins: an Indian experience. In: *Biopesticides and Pest Management: Progress and Potential*, Koul, O., Dhaliwal, G. S., Marwaha, S. S. and Arora, J. K. (Eds). Campus Books International: New Delhi, 96–112.

James, C. (2002) Preview: Global status of commercialized transgenic crops: 2002 ISAAA Briefs, No. 27, ISAAA, Ithaca, N.Y.

Kranthi, K. R., Kranthi, S. and Wanjari, R. R. (2001) Baseline susceptibility of Cry1A toxins to *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in India. *Int. J. Pest Manag.* **45**: 141–145.

Laemmli, U. K. (1970) Cleavage of structural proteins during the assembly of the head of bacteriophage T_4. *Nature (Lond.)* **227**: 680–685.

McCaffery, A. R. (1999) Resistance to insecticides in heliothine Lepidoptera: a global view. In: *Insecticide Resistance from Mechanisms to Management*, Denholm, I., Pickett, J. A. and Devonshire, A. L. (Eds). CABI and the Royal Society: London, 59–74.

Mohan, M. and Gujar, G. T. (2002) Geographic variation in susceptibility of the diamondback moth, *Plutella xylostella* (L) (Lepidoptera: Plutellidae) to *Bacillus thuringiensis* spore-crystal mixtures and purified crystal proteins and associated resistance development in India. *Bull. Ent. Res.* **92**: 489–498.

Nagarkatti, S. and Prakaash, A. (1974) Rearing of *Heliothis armigera* (Hübner) on an artificial diet. *Tech. Bull. Commonwealth Institute of Biological Control. Bangalore, India* **17**: 169–173.

Puri, S. N., Murthy, K. S. and Sharma, O. P. (1998) *Integrated Pest Management in Cotton, ext. Folder 5*, NCIPM and Ministry of Agriculture: New Delhi.

Ridgeway, R. L., Bell, A. A., Veech, J. A. and Chandler, J. M. (1984) Cotton protection practices in the USA and world. Section A: insects. In: *Cotton Agronomy Ser. 24*, Kohel, R. J. and Lewis, C. F. (Eds). Am. Soc. Agron.: Madison, WI, 265–287.

Ross, G. E. S. (1977) *Maximum Likelihood Programme*, The numerical algorithms Group, Rothamsted Experiment Station: Harpenden, UK.

Thiery, I. and Frachon, E. (1997) Identification, isolation, culture and preservation of entomopathogenic bacteria. In: *Manual of Techniques in Insect Pathology*, Lacey, L. A. (Ed). Academic Press: London, 55–77.

Wu, K., Guo, Y. and Lv, N. (1999) Geographic variation in susceptibility of *Helicoverpa armigera* (Lepidoptera: Noctuidae) to *Bacillus thuringiensis* insecticidal protein in China. *J. Econ. Entomol.* **92**: 273–278.

Wu, K. M., Guo, Y. Y., Lv, N., Greenplate, J. T. and Deaton, R (2002) Resistance monitoring in *Helicoverpa armigera* (Lepidoptera: Noctuidae) to *Bacillus thuringiensis* insecticidal protein in China. *J. Econ. Entomol.* **95**: 826–831.

(Received 29 August 2003; accepted 8 March 2004)

ENTOMON **29(1)**: 81–84 (2004)
Short Communication No. ent.29114

Effect of bitter apple, *Citrullus colocynthis* (L.) Schrad seed extracts against pulse beetle, *Callosobruchus maculatus* Fab. (Coleoptera: Bruchidae)

S. Prabu Seenivasan, M. Jayakumar, N. Raja and S. Ignacimuthu*

Entomology Research Institute, Loyola College, Chennai 600034, India
Email: eri_lc@hotmail.com

ABSTRACT: Present study reports the bioefficacy of different solvent extracts of *Citrullus colocynthis* seeds against pulse beetle *Callosobruchus maculatus*. Anti-oviposition, F1 adult emergence, ovicidal and repellent activity of the plant extracts were recorded on treated cowpea seeds of *Vigna unguiculata*. All the extracts showed significant effect. Maximum antioviposition activity was observed in petroleum ether extract (64.97%). Significant reduction in F1 adult emergence was recorded in petroleum ether (94.14 and 92.86 %) and ethyl acetate (93.29 and 93.26%) extracts respectively. High ovicidal activity was observed in petroleum ether extract (95.31%) followed by ethyl acetate extract (87.5%). *C. colocynthis* extract did not affect germination of seeds. © 2004 Association for Advancement of Entomology

KEYWORDS: *Citrullus colocynthis*, biological activity, *Callosobruchus maculatus*

Bitter apple, *Citrullus colocynthis,* belongs to the family Cucurbitaceae; it is a perennial herb having climbing stem; it contains various secondary metabolites, which are used to treat ascites, jaundice, urinary diseases and rheumatism (Chopra, 1933). The seed contains active principles of colocynth including a bitter amorphous alkaloid, resin and phytosterolin (ipuranol), 2 phytosterols, 2 hydrocarbons, saponin, alkaloid, poly saccharide or aclucoside, and tannin (Wealth of India, 1950). The pulse beetle *Callosobruchus maculatus* is a dominant stored product pest in tropical and sub-tropical regions, and attacks wide range of legumes (Giga and Smith, 1986). There is no earlier report on the biological activity of this plant extract against *C. maculatus*.

Shade dried seeds were powdered using electric blender and 100 g of the powder was sequentially extracted with 500 ml of petroleum ether, ethyl acetate and alcohol at 12 h intervals and filtered. The solvent from the filtrate was evaporated using rotary evaporator to obtain solvent free residue. Appropriate concentrations (0.6, 1.25, 2.5 and 5%) were prepared by mixing the residue with acetone and used for experiments.

*Corresponding author

© 2004 Association for Advancement of Entomology

No choice method was used for oviposition deterrent activity; for this cowpea seeds were cleaned and sterilized at 45 °C for 6 hrs to kill the eggs and developing larvae of *C. maculatus*. For each concentration, 250 cowpea seeds were taken in a conical flask and mixed with 2 ml of plant extracts and the seeds treated with acetone and untreated seeds were used as control. After solvent evaporation the seeds were divided into five lots each having 50 seeds and stored in plastic containers (8 × 6.5 cm); 5 pairs of newly emerged adult *C. maculatus* were introduced in to the plastic containers. After 15 days, the adults introduced were removed and the number of eggs laid on treated and control seeds were recorded and the percentage of oviposition deterrence was calculated. The experimental set up was kept undisturbed till the emergence of F1 adults from the treated seeds. The number of F1 adults emerged in each replication were recorded and the percentage reduction of F1 adult emergence was calculated. For the evaluation of ovicidal activity, three hundred cowpea seeds were taken in glass jar (17.5 × 8.5 cm) and 20 pairs of newly emerged adults were introduced. After 24 hr, 250 seeds bearing eggs were removed from the glass jar and separated into five lots each having 50 seeds. Before treatment the number of eggs in each seed was counted; the seeds bearing eggs were treated with selected concentrations of the plant extracts and controls as mentioned earlier. After seven-days the hatched and unhatched eggs on treated seeds and control seeds were recorded and the percentage of ovicidal activity was calculated. Five replicates were maintained for each treatment.

Multi-arm glass olfactometer with four arms projecting out (15 cm length and 2 cm diameter) with equal gap of 90° was used for repellency test. The end of each arm was fitted with a plastic container (8 × 6.5 cm). Filter paper strips (6 × 4 cm) were dipped with 5% concentration of the seed extracts and controls as mentioned earlier air-dried and placed in plastic jars of olfactometer and covered with muslin cloth. Fifty newly emerged adult *C. maculatus* were introduced into the central opening of the olfactometer. After 1 h, the number of beetles found in each jar was recorded and the percentage of repellency was calculated.

For the impact of plant extract on germination, 1300 seeds were selected randomly and treated with different concentrations of plant extracts and controls as mentioned earlier. The treated seeds were placed in a petridish containing moist cotton wool and rewetted with distilled water. Percentage of seeds germinated was recorded after 5 days and compared with control. The experiments were replicated four times for all concentrations with 25 seeds per replication.

Mean and standard deviation were calculated for all the variables. Data from the experiments were subjected to two-way analysis of variance (ANOVA). Further the significant difference between the means was separated using Least Significant Difference (LSD) test.

The results clearly indicated that petroleum ether extract of *C. colocynthis* seed had significant ($P < 0.05$) oviposition deterrent activity against *C. maculatus* (Table 1). Significant oviposition reduction was recorded in 5% concentration of petroleum ether extract (64.97%) followed by ethyl acetate (47.99%). Significant reduction in F1 adult emergence was recorded in petroleum ether extract at 1.25% concentration

TABLE 1. Biological activity of *Citrullus colocynthis* seed extract against *Callosobruchus maculatus*

Extract	Petroleum ether		Ethyl acetate		Alcohol	
Oviposition deterrent activity						
Concentration	No. of eggs laid*	% reduction	No. of eggs laid*	% reduction	No. of eggs laid*	% reduction
0.6%	292.2 ± 14.77^{b}	20.16	236.2 ± 18.13^{b}	8.73	307 ± 9.67^{a}	1.16
1.25%	172.2 ± 13.57^{c}	52.95	231.8 ± 10.46^{c}	10.43	277.6 ± 16.36^{b}	10.62
2.5%	159.8 ± 12.38^{d}	56.34	155.2 ± 10.23^{d}	40.03	244.2 ± 15.22^{c}	21.38
5%	128.2 ± 11.95^{e}	64.97	134.6 ± 8.76^{e}	47.99	187.4 ± 11.74^{d}	39.67
Control	366 ± 26.71^{a}	—	258.8 ± 19.31^{a}	—	310.6 ± 11.35^{a}	—
F1 Adult emergence						
Concentration	No. of F1 adults emerged*	% reduction	No. of F1 adults emerged*	% reduction	No. of F1 adults emerged*	% reduction
0.6%	132.4 ± 1.52^{b}	42.98	72.6 ± 3.72^{b}	42.01	141.4 ± 5.46^{b}	7.09
1.25%	54 ± 3.85^{c}	76.74	36.2 ± 6.11^{c}	71.09	123.4 ± 5.46^{c}	18.92
2.5%	46.2 ± 4.26^{d}	80.1	26.4 ± 2.65^{d}	78.91	70.2 ± 8.57^{d}	53.89
5%	13.6 ± 3.26^{e}	94.14	8.4 ± 2.06^{e}	93.29	34.2 ± 2.48^{e}	77.52
Control	232.2 ± 13.82^{a}	—	125.2 ± 10.91^{a}	—	$152.2 \pm 9.45a$	—
Ovicidal activity						
Concentration	No. of eggs hatched*	% ovicidal activity	No. of eggs hatched*	% ovicidal activity	No. of eggs hatched*	% ovicidal activity
0.6%	33.36 ± 1.78^{b}	45.15	37.66 ± 4.26^{b}	38.08	51.48 ± 4.86^{b}	15.35
1.25%	18.91 ± 3.84^{c}	68.91	19.76 ± 4.15^{c}	67.51	43.57 ± 3.75^{c}	28.36
2.5%	9.03 ± 1.80^{d}	85.15	11.24 ± 2.02^{d}	81.51	36.87 ± 3.77^{d}	39.38
5%	2.85 ± 0.66^{e}	95.31	7.60 ± 1.09^{e}	87.5	28.47 ± 1.88^{e}	53.19
Control	60.82 ± 1.88^{a}	—	60.82 ± 1.88^{a}	—	60.82 ± 1.88^{a}	—

*Mean value of five-replication ± SD. Within the column, different alphabets indicate statistically significant ($P < 0.05$) difference by LSD.

(76.74%) and at 5% concentration (94.14%). Ethyl acetate and alcohol extracts exhibited the reduction of F1 adult emergence at higher concentrations. Methanol and ethyl acetate extract of *Azadirachta indica* (Mahgoub, 1992), *Lantana camara* (Rahman and Schmidt, 1999) *Vitex negundo, Cassia fistula* (Raja *et al.*, 2000) and *Andrographis paniculata* (Annie Bright *et al.*, 2001) have been reported for the oviposition deterrence against *C. maculatus.*

Repellent activity increases the potential value of the materials in protecting grains from the attack by stored product insect pest (Bekele *et al.*, 1997). In the olfactometer study the percentage of repellent activity was maximum in petroleum ether extract (50.16) followed by ethyl acetate extract (28.05). This plant extract possesses various biological activities against *C. maculatus* as has been reported for the first time.

REFERENCES

Annie Bright, A., Babu, A., Ignacimuthu, S. and Dorn, S. (2001) Efficacy of *Andrographis paniculata* Nees. on *Callosobruchus chinensis* L. during post harvest storage of cowpea. *Indian J. Exp. Biol.* **39**: 715–718.

Bekele, A. J., Obeng-Ofori, D. and Hassanali, A. (1997) Evalution of *Ocimum kenyense* (Ayobangira) as source of repellence, toxicants and protactants in storage against three major stored product insect pest. *J. Appl. Ent.* **121**: 169–173.

Chopra, R. N. (1933) *Indigenous Drugs of India*, The Art Press: Calcutta, 121–122.

Giga, D. P. and Smith, R. H. (1986) Egg production and development of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) on several commodities at two different temperatures. *J. Stored Prod. Res.* **23**: 9–15.

Mahgoub, S. M. (1992) Neem seed extracts and powders as grain protectants to cowpeaseeds against the cowpea weevil *Collosobnechus maculatus* Fab.. *Egyptian J. Agri. Res.* **70**: 487–489.

Rahman, M. M. and Schmidt, G. H. (1999) Effect of *Acrous calamus* (L.) (Aracea) essential oil vapors from various origins on *Callosobruchus phaseoli* (Gyllenhal) (Coleoptera: Bruchidae). *J. Stored Prod. Res.* **35**: 285–295.

Raja, N., Albert, S. and Ignacimuthu, S. (2000) Effect of solvent residues of *Vitex negundo* Linn. and *Cassia fistula* Linn. on pulse beetle, *Callosobruchus maculatus* Fab. and its larval parasitoid, *Dinarmus vagabundus* (Timberlake). *Indian J. Exp. Biol.* **38**: 290–292.

Wealth of India, (1950) A Dictionary of Indian Raw Materials and Industrial Products. *Raw Materials* **Vol. II**: 185–186.

(Received 16 July 2003; accepted 29 December 2003)

ENTOMON **29(1):** 85–87 (2004)
Short Communication No. ent.29115

Biology of *Euproctis scintillans* Walk. (Lepidoptera: Lymantriidae) on its new host *Robinia pseudoacacia* L. from Himachal Pradesh

Shamila Kalia*[1] and V. P. Pandey[2]

[1]*Forest Research Institute, P.O. New Forest, Dehradun 248006, India*
[2]*Himalayan Forest Research Institute, Panthaghati, Shimla 171009, India*

ABSTRACT: *Euproctis scintillans* W. is an important polyphagous pest. It causes upto 40% damage to the foliage of *Robinia pseudoacacia* L. in some areas of Himachal Pradesh. Heavy attack during monsoons results in large defoliation of the trees. Biology of the insect and the external morphology of moth, pupa, larva and egg is described for the first time on this host in the study.
© 2004 Association for Advancement of Entomology

KEYWORDS: *Euproctis scintillans, Robinia pseudoacacia* Himachal Pradesh

INTRODUCTION

Robinia pseudoacacia L. is an important multipurpose forest tree of Himachal Pradesh. It is known for its medicinal value and also as an important fodder tree. It is also being introduced as an agro-forestry species in some regions. During regular surveys the leaves of *R. pseudoacacia* were found damaged heavily by *Euproctis scintillans* W. Upto 40% defoliation was observed in some areas. Beeson (1941), Mathur and Balwant Singh (1954–61) and Browne (1968) have reported that the larva of this insect is polyphagous on the foliage of *Acacia mearnsii, Acacia nilotica indica, Aesculus indica, Aleurites montana, Anacardium occidentale, Buchanania latifolia, bamboos, Cassia fistula, Castanea sativa, Dalbergia sissoo, Ficus bengalensis, Ficus glomerata, Havea brasiliensis, Lagerstroemia indica, Lantana aculeata, Mangifera indica, Pithecellobium dulce, Quercus incana, Shorea robusta, Tamarindus indica, Terminalia bellerica* and *Terminalia catappa*. But the biology of this insect on *Robinia pseudoacacia* has not been studied so far and hence this research has been carried out.

The biology of *E. scintillans* W. was studied under laboratory conditions at Himalayan Forest Research Institute, Shimla from June 2000 to January 2001. The eggs collected from the field were placed in beakers lined with moist filter paper

*Corresponding author

© 2004 Association for Advancement of Entomology

and covered from above with muslin cloth. The newly hatched larvae were daily transferred to different beakers with the help of a brush. Fresh tender leaves were provided to the first instar larvae every 24 hours. Larvae were observed daily and the data recorded on moulting, duration and size of each larval instar. Pupation and pupal period were also recorded. Observations were also taken on the emergence longevity and fecundity of the adults. Adults kept were observed for assessing mating, pre-oviposition and oviposition periods.

Moth appeared in the month of September. Mating occurs after sunset. The preoviposition period lasted 9–12 hrs and then the adults started oviposition. A single female laid 10–205 eggs (Av. 123.3 ± 12.6 eggs). Oval plate yellow (0.8 × 0.8 mm) and covered by pale greenish coloured mass of ovipositor scales. After hatching they turn white in colour. Incubation period lasted 3–5 years (4.30 ± 0.48 days). Only one larva hatched from each egg (No. 100 eggs) first instar larva is very active yellowish brown in colour covered with dark coloured hair. Length 1.0 mm and breadth 0.3 mm. Head is dark brown colour. This stage lasted for 3–9 days (Av. 4.80 ± 0.41 days) after which is moulted. Second instar larva is brownish yellow and very active larva. Length 5.0 mm and breadth 0.3 mm. Black tuff of hair present on the whole body. Head is dark with prominent mandibles. Total period of larval instar is 4–10 days (Av. 5.2 ± 0.55 days). Third instar larva is brown coloured with a broad dorsal yellow stripe and black tuffs of hair on the whole body. Length 15 mm. Head dark reddish brown with prominent mandibles. Very active and voracious feeder. Moults in 4–11 days (av. 4.9 ± 0.65 days). Fourth instar larva is voracious feeder, active, very hairy, dark brown with a series of crimson lateral tubercles on a yellow line bearing tufts of grey hair. Broad dorsal yellow stripe. A yellow spot on the anal somite and with prominent dark brown coloured mandibles 20 mm long and 0.8 mm broad. This stage lasts 6–10 days (7.9 ± 1.0 days). Fifth instar larva is dirty brown in colour on the dorsal and cream in colour on the dorsal and cream in colour on the ventral surface. It is exactly like the fourth instar larva but its size increases in length 28–30 mm and 2 mm breadth. Head also dark reddish brown with prominent mandibles initially feeds voraciously but turns sluggish and stops feeding when fully mature. This stage lasts for 8–14 days (Av. 10.23 ± 2.1 days).

Pupa is light yellow initially and gradually change to reddish black in colour. Bilaterally symmetrical and elongated. Pre-pupal period lasts for 3–5 days (Av. 4.3 ± 0.56 days) and the average period for pupa to adult emergence was 10–18 days (Av. 16.39 ± 2.0 days).

The adult moths are brown and yellow coloured with a wing span of 3.5 cm Head yellow, thorax brown and abdomen brown. The anal tuft orange. Forewing vinous brown, irroated with dark scales, which colour extends as two spurs across the yellow margin. Costa often yellow. Hind wing fiscous brown with a broad dark yellow margin.

In the laboratory the adult moths mated after sunset and laid eggs in groups usually on the leaves, covered by a large secretion of ovipositor scales. After the incubation period the eggs hatched and it was observed that only one larva hatched from each egg. There wasn't a single case where the number increased [$n = 100$]. The first instar

larva remains on the outer edge of the egg shells exposed from the ovipositor scales for sometime and then within minutes crawl to the tender leaves and start feeding. All the instars except the last instar larvae which was sluggish and dull, feed gregariously on the leaves. The larva becomes immobile and inactive, stops feeding, shrinkage and thickening of body occurs before forming a pupa. The mature larva spins a silken web of creamish white colour entangling leaves along it forming a cocoon. The cocoon is greatly elongated, enclosed and fastened by silken threads and leaves. On emergence, the adults remained inactive with wings compressed for 1–2 hours. The life cycle from egg to adult was 58.02 ± 0.69 days.

REFERENCES

Beeson, C. F. C. (1941) *The Ecology and Control of Forest Insects of India and their Neighbouring Countries*, Vasant Press: Dehradun, p 785.

Browne, F. G. (1968) *Pests and Diseases of Forest Plantations*, Clarendon Press: Oxford, p 1330.

Mathur, R. N. and Balwant Singh (1954-61) List of insect pests of forest plantations in India and the adjacent countries. *Ind. For. Bull. (N.S.). Ento.* **171 pts**: 1–1.

(Received 10 June 2003; accepted 23 January 2004)

ENTOMON 29(1): 89–95 (2004)
Short Communication No. ent.29116

Food plants of some Indian Cassidines (Coleoptera: Chrysomelidae)

T. Kalaichelvan[1], K. K. Verma*[2] and B. N. Sharma[3]

[1]*Maitri Baag Zoo, Bhilai Steel Plant, Bhilai, Chhattisgarh 400006, India*
[2]*HIG-1/327, Housing Board Colony, Borsi, Durg, Chhattisgarh 491001, India*
[3]*Govt. Arts College, Vaishali Nagar, Bhilai, Chhattisgarh 490001, India*

ABSTRACT: New food plants of 13 cassidine species have been recorded. They belong to four families, Convolvulaceae, Amaranthaceae, Meliaceae and Rhamnaceae. It has been noted that those cassidines, which live on Convolvulaceae with hairy leaves, have extra long setae on the distal part of hind tibiae.
© 2004 Association for Advancement of Entomology

KEYWORDS: Convolvulaceae, Amaranthaceae, tibial hairs, cassidines, host records

Cassidinae commonly known as tortoise beetles, are the most specialised of the chrysomelid subfamilies (Jolivet and Verma, 2002). Some record of food plants of Indian cassidines is available in Maulik (1919); Rawat and Bodi (1972); Pajni and Bansal (1977); Takizawa (1980); Visalakshi *et al.* (1980); Verma and Shrivastava (1985), George and Venkataraman (1987), Borowiec (1999); Borowiec *et al.* (2001) and Swietojanska (2001). But the data available in this respect, is scanty. Hence we are presenting here observations on food plants of cassidines made during our field work.

Observations have been made in the field in and around the twin city of Durg–Bhilai (Chhattisgarh, India). Most observations have been repeated in laboratory by keeping the insects in glass jars with fresh leaves.

Observations are summarised in Table 1. The following generalizations can be made with respect to the food plants of the various cassidine species studied.

Aspidimorpha furcata (Thunberg). It feeds on both Convolvulaceae with smooth leaves as well as those with hairy leaves, but mostly on those with hairy leaves. In late October and early November, when the monsoon period is over and hairy leaf *Ipomoea* plants have dried up, the insect seems to shift from such plants to smooth leaf *Ipomoea*. The present observations as well as the data included in Borowiec (1999) and Swietojanska (2001) show that this species is oligophagous on Convolvulacea.

*Corresponding author

© 2004 Association for Advancement of Entomology

TABLE 1. Food plants of Cassidinae recorded from Durg – Bhilai

Food plant	Cassidine species												
	Aspidimorpha furcata	*Aspidimorpha miliaris*	*Aspidimorpha sanctaecrucis*	*Conchyloctenia nigrovittata*	*Cassida circumdata*	*Cassida exilis*	*Cassida obtusata*	*Cassida residua*	*Chiridopsis promiscua*	*Chiridopsis nigropunctata*	*Glyphocassis trilineata*	*Oocassida pudibunda*	*Rhyticocassis indicola*
CONVOLVULACEAE													
Convolvulus nummularius	√			√	√						√		√
*Evolvulus alsinoides**	√												
Ipomoea aquatica	√**	√	√	√	√**				√	√	√		√
I. batatas	√**	√**	√	√	√**				√	√	√		√
I. coccinea	√												
I. fistulosa	√	√	√	√	√				√	√	√		√
*I. hispida**	√										√		
*I. indica**	√										√		
I. obscura	√										√		√
I. palmata	√	√	√		√**				√	√	√		√
*I. pestigridis**	√										√		
*I. pilosa**	√										√		
I. violacea	√	√	√	√	√				√	√	√		√
Ipomoea sp? (white sweet potato)	√**	√**	√**		√**				√**	√**	√**		√**
Ipomoea sp? (with yellow colour flower)	√**	√**	√**	√**	√**				√**	√**	√**		√**

TABLE 1. Continued . . .

Food plant	Cassidine species													
	Aspidimorpha furcata	*Aspidimorpha miliaris*	*Aspidimorpha sanctaecrucis*	*Conchyloctenia nigrovittata*	*Cassida circumdata*	*Cassida exilis*	*Cassida obtusata*	*Cassida residua*	*Chiridopsis promiscua*	*Chiridopsis nigropunctata*	*Glyphocassis trilineata*	*Oocassida piidibunda*	*Rhyticassis indicola*
Merremia emerginata	√			√	√				√	√	√		√
M. tridentate	√			√							√		√
AMARANTHACEAE													
Alternanthera sessilis						√	√**						
A. tenella						√	√	√					
Amaranthus bilitum						√	√	√					
A. philoxeroides						√	√	√					
A. simplex		√				√	√	√					
Celosia argentea						√	√**	√					
Celosia sp?						√	√**	√					
MELIACEAE													
Melingtonia hartensis						√							
RHAMNACEAE													
Ziziphus jujuba						√						√	

√ Fed on leaves; * plants with hairy leaves; All the hosts, not marked with ** , are additions to Borowiec's (1999) host list of cassidines.

A. miliaris (Fabricius). When *A. miliaris* adults were kept with only hairy leaves of Convolvulaceae in a culture jar, they did not feed, and died. In the field, in the month of March, *A. miliaris* adults are sometimes seen on *Amaranthus simplex*. At that time, onset of summer diapause is quite evident in the insect. At the same time, leaves of the plant showed round fed away areas, similar to those made by *A. miliaris* in leaves of *Ipomoea fistulosa*. It was, therefore suspected that the insect was feeding on the leaves of *A. simplex*. To confirm this *A. miliaris* adults were kept with *A. simplex* leaves in glass jars. They fed for a day or two on the leaves, and then feeding stopped.

A. sanctaecrucis (Fabricius). Generally found on *Ipomoea fistulosa* and *Ipomoea* climbers with smooth leaves mostly in drier areas. This species may occur along with *Aspidimorpha miliaris* on an *Ipomoea fistulosa* plant, but this situation is rare. (Niche separation between the two species of *Aspidimorpha* has been described in detail by Verma and Shrivastava, 1985). It may be noted that *A. sanctaecrucis* is not found on *Ipomoea* species with hairy leaves.

Conchyloctenia nigrovittata (Boheman). It feeds on various species of Convolvulaceae with smooth leaves. An interesting fact is that it is generally associated with another cassidine, *Rhytidocassis indicola* (=*Cassida indicola*). Not only adults but also larvae, pupae and oothecae of the two species may be present together on the same leaf. *Con. nigrovittata* is commonly seen on the host plant upto 30 cm from the ground, and has been rarely observed above 60 cm.

Cassida circumdata (Herbst). During summer, it lives mostly on *Ipomoea aquatica*. During rainy season it is found on almost all Convolvulaceae with smooth leaves. During this period it prefers *Ipomoea* creepers and runners. In early winter it changes the host plants and shifts to *I. palmata, I. batatas and I. fistulosa*, but in severe cold it not seen in the field.

C. exilis (Boheman). During monsoon rains, this beetle is found on various Amranthaceae. During this period it may be feeding also on *Zizyphus jujuba*, but mostly on sweet varieties of the plant, and rarely on sour varieties. Developmental stages of the insect, however have not been observed on *Zizyphus jujuba*. On this plant host, *C. exilis* may be associated with *Oocassida pudibunda*. In early February and March, it is found mostly on *Melingtonia hartensis*. The insect could not be collected in mid and late summer.

C. obtusata (Boheman). During monsoon rains, it could be observed on various members of Amaranthaceae. It could not be seen on any plant and in any other season.

C. residua (Weise). It is found on *Alternanthera tenella*, growing near water and on the water plant *Amaranthus philoxeroides*. It only rarely occurs on species of *Celosia*. It actively feeds all through the year, except when it is very cold. (*C. obtusata* and *C. residua* have been synonymised by Borowiec, 1999. But we have repeatedly reared *C. residua* in culture jars, and have never found *C. obtusata* like individuals in the resulting progeny. However, their host plant ranges are very similar.)

Chiridopsis promiscua (Boheman). Generally found on *Ipomoea fistulosa* in drier area. In early winter it occurs also on *Ipomea* climbers and rarely on *I. palmata* and *Merremia* species. It has never been found on Convolvulaceae with hairy

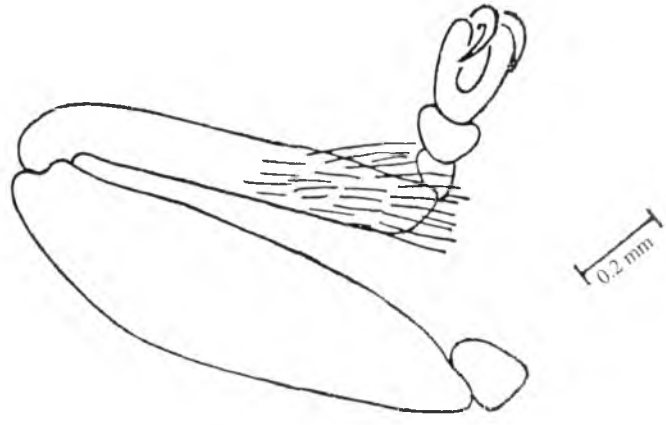


FIGURE 1. Hind leg of *Aspidimorpha furcata*.

leaves. (Borowiec, 2001 has synonymised *Ch. promiscua*, Boheman with *Chiridopsis bipunctata*, Linnaeus.).

C. nigropunctata (Borowiec and Ghate). Found on Convolvoulaceae with smooth leaves, including species of *Ipomoea* and *Merremia*.

Glyphocassis trilineata (Hope). It occurs on various species of Convolvulaceae, both with smooth and hairy leaves.

Oocassida pudibunda (Boheman). Generally found on sour fruit *Zizyphus jujuba* and less commonly on sweet varieties. It chooses young and tender leaves.

Rhytidocassis indicola (=*Cassida indicola*) (Duvivier). Found on smooth leaf Convolvulaceae, generally upto the height of 60 cm from the ground, and rarely upto 120 cm.

Among the Convolvulaceae-feeding cassidine species studied, *Glyphocassis trilineata* and *Aspidimorpha furcata* both choose plants with hairy as well as smooth leaves, whereas the remaining species are confined to plants with non-hairy leaves. Choice of food plants by insects is determined by several factors (Remmert, 1980). But in the case of cassidines could some features of the leg structure be playing a role in the choice of hairy and smooth plants? In order to answer this question, we have examined the hind leg structure of all the Convolvulaceae feeding cassidines, covered in this study, and the only difference, which has been noted, is that in the hairy leaf feeding species the hairs on the distal part of the tibia are longer, more numerous and present a denser arrangement than in the remaining species. (Figs 1 and 2). Perhaps such tibial hairs are helpful in moving on the velvety surface of a hairy leaf.

Jolivet (1988, 1995) has pointed out that cassidines are mostly oligophagous and mostly feed on dicotyledons. Our observations agree with this. We could not collect any cassidine from a monocot. Jolivet (1988) has given a list of 21 angiosperm families on which cassidines have been recorded. In our area of collection we could

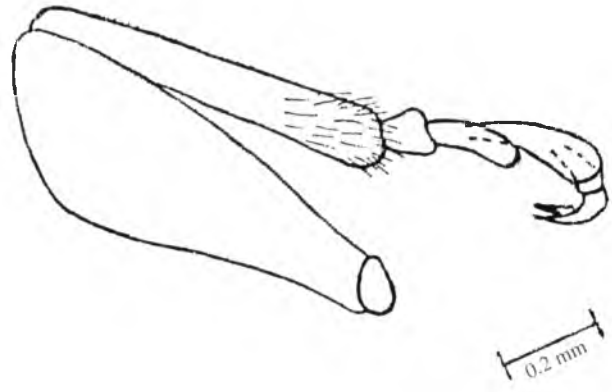


FIGURE 2. Hind leg of *Rhytidocassis indicola*.
(N.B.: In either figure only those hairs have been shown which are present on the distal part of the tibia.)

observe them only on 4 families, *viz.* Convolvulaceae, Amaranthaceae, Meliaceae and Rhamnaceae.

Borowiec (1999) has recorded host plants of different cassidine species. For the species covered in the present study, the host plant list needs to be updated. The new host records are indicated in Table 1.

ACKNOWLEDGEMENTS

We are obliged to Dr. M. L. Naik of the Bioscience Dept. of Pt. Ravi Shankar University, Raipur, and to Prof. D. Karkun of Govt. Arts and Science College, Durg for identification of plants. The first author thanks the Principal Dr (Mrs.) M. Arora and Head of the Dept. of Zoology, Mrs. P. Ghosh, Govt. Arts and Science College, Durg for facilities to work. Thanks are also due to Prof. L. Borowiec for encouragement.

REFERENCES

Borowiec, L. (1999) *A World Catalogue of the Cassidinae (Col., Chrysomelidae)*. Biologica Silesiae: Wroclaw, p 476.

Borowiec, L. (2001) New records of Asian and Australopapuan Cassidinae, with description of five new species of Cassida L. from Thailand (Col. chrysomelidae, Cassidinae). *Genus* **12(4)**: 493–562.

Borowiec, L., Ranade, S., Rane, N. and Ghate, H. V. (2001) *Chiridopsis rubromaculata* n. sp. from India, and notes on its bionomy and immature stages (Col., Chrysomelidae, Cassidinae). *Genus* **12(3)**: 361–371.

George, and Venkataraman, K. (1987) Occurrence and life history of *Cassida circumdata* Herbst (Col., Chrysomelidae) in Keoladeo National Park, Bharatpur, India. *Journal of Bombay Natural History Society* **84**: 248–253.

Jolivet, P. (1988) Food habits and food selection of Chrysomelidae. Bionomic and evolutionary perspectives. In: *Biology of Chrysomelidae*, Jolivet, P., Petitpierre, E. and Hsiao, T. H. (Eds). Kluwer Academic Publishers: The Netherlands, 1–24.

Jolivet, P. (1995) Reflexions sur les plantes-hotes des Chrysomelides (Col.). *L'Entomologiste* **51(2)**: 77–93.

Jolivet, P. and Verma, K. K. (2002) *Biology of Leaf Beetles*, Intercept: Andover, UK, p 327.

Maulik, S. (1919) *Fauna of British India Including Ceylon and Burma, Volume on Coleoptera, Chrysomelidae (Hispinae and Cassidinae)*, Taylor and Francis: London, p 439.

Pajni, H. R. and Bansal, R. K. (1977) First report on the chrysomelid fauna of Chandigarh. *Research Bulletin (Science), Punjab University* **28**: 55–59.

Rawat, R. R. and Bodi, B. N. (1972) Preliminary study on the biology and natural enemies of tortoise-beetle, *Oocassida pudibunda*, Boh. (Coleoptera: Chrysomelidae: Cassidinae) in Madhya Pradesh. *Indian Journal of Agricultural Sciences* **42(9)**: 854–856.

Remmert, H. (1980) *Ecology*, Springer-Verlag: Berlin, New York, p 289.

Swietojanska, J. (2001) *A revision of the tribe Aspidimorphini of the Oriental Region. Genus*, (supplement). 318 pp. + 18 colour plates.

Takizawa, H. (1980) Immature stages of some Indian Cassidinae (Col., Chrysomelidae). *Insecta Matsumurana* **21**: 19–48.

Verma, K. K. and Shrivastava, R. K. (1985) Separate niches for two species of *Aspidomorpha* living on *Ipomoea fistulosa* M. and deBary (Col., Chrysomelidae). *Entomography* **3**: 437–446.

Visalakshi, A., Santhakumari, K., Koshy, G. and Nair, M. R. G. K. (1980) Biological studies on *Aspidomorpha furcata* Thunb. (Chrysomelidae: Cassidinae: Col.). *Entomon* **5(3)**: 167–169.

(Received 3 April 2003; accepted 10 October 2003)

ENTOMON 29(1): 97–100 (2003)
Short Communication No. ent.29117

Efficacy of different insecticides as baits against grown up larvae of the red hairy caterpillar, *Amsacta albistriga* (Lepidoptera: Arctiidae)

K. Manjula*

Agricultural Research Station, Anantapur 515001, Andhra Pradesh, India

ABSTRACT: A field trial was conducted in farmers' fields for two years to test the efficacy of some commonly used insecticides as baits to later instars of Red hairy caterpillar. The experiment was conducted with nine treatments including untreated control and replicated thrice. The insecticides used were monocrotophos, chlorpyriphos, quinalphos, methomyl, thiodicarb and carbaryl. Chlorpyriphos was found to be superior in recording highest larval mortality. Monocrotophos, methomyl and quinalphos were also effective. Thiodicarb and carbaryl were relatively less effective chemicals among the six insecticides used. © 2003 Association for Advancement of Entomology

KEYWORDS: Insecticidal bait, Red hairy caterpillar, later instar, larval mortality

Groundnut is an important rainfed crop being grown over 10.0 lakh hectares in Anantapur district. For the past 10–15 years, The Red hairy caterpillar, *Amsacta albistriga* Walker (RHC) has been one of the major constraints to this crop in several places of the district particularly too in red soils. The moths emerge coinciding with monsoon rains and caterpillars cause damage by scrapping the leaves in early stages and devouring the foliage as they grow.

Early instars (I to III) are susceptible to insecticides either dust or spray but grown up caterpillars are resistant to most of the conventional insecticides. Keeping this in view, an experiment was conducted in farmers' holdings for two years to evaluate the efficacy of six commonly used insecticides as baits against later instars.

During *kharif* 2000, the trial was laid out in RBD with 9 treatments at two villages (Kunuthuru of Dharmavaram Mandal and Alamur of Ananatapur Mandal) during the months of August–September. Groundnut fields in which only later instar RHC are present were selected. Each treatment was imposed in one acre and replicated

*Present address: Department of Entomology, S.V. Agricultural College, Tirupati 517502, Andhra Pradesh.

© 2003 Association for Advancement of Entomology

thrice. The treatments were monocrotophos 36 EC (Nuvacron), chlorpyriphos 20 EC (Durban), quinalphos 25 EC (Ekalux) and methomyl 80 SL (Dunet). Composition of bait was ricebran, jaggery and the insecticide at normal dose (5 kg; 500 gms; 0.5 l/acre) and the double dose (10 kg; 1 kg; 1 l/acre).

During 2001, RHC infested fields were selected at Rekulakunta of Bukkarayasamudram Mandal for the experiment. Thiodicarb and carbaryl were introduced in place of monocrotophos and methomyl. To reduce the cost of treatment, the quantity of insecticides was reduced (Table 1). The quantity of rice bran was slightly increased to 6 kg/acre.

To prepare the bait, jaggery was made into pieces and boiled with some amount of water to melt. Rice bran was weighed, placed on a tarpaulin and the required volume of insecticide was sprinkled on it and mixed. The jaggery syrup was then added. The material was formed in the shape of some loose balls, flakes and also powder.

Total number of caterpillars present in $2m^2$ areas was recorded at three random places. Then bait was applied and the larva mortalities were recorded after 3 days. Mean per cent larval mortalities were calculated and the data was subjected to RBD analysis.

The per cent larval mortalities in different treatments are shown in the Table 1. During the first year, the highest per cent larval mortality was recorded with chlorpyriphos (97.22) at double dose (500 g a.i./ha). The nest best treatments were monocrotophos and methomyl at double dose (900 g and 600 g a.i./ha) which recorded 92.90 and 91.59 per cent larval mortalities respectively. At normal doses also the above three chemicals reduced the larval numbers to more than 70 per cent. Significant mortalities were recorded between the higher and lower doses of all the four chemicals tested (Table 1). Quinalphos was found relatively less effective among the four chemicals which recorded 87.23 and 84.18 per cent at higher and lower doses respectively.

During the second year also chlorpyriphos occupied the first place by recording 88.85 per cent larval mortality when used @400 ml per acre. Quinalphos also gave good mortality (83.01 per cent) at 400 ml per acre. Thiodicarb and carbaryl were found relatively less effective chemicals. Untreated control recorded nil larval mortality.

Larval mortality was gradually decreased with reduction in the quantity of chemical in all the cases. The fumigant action of chlorpyriphos, methomyl in addition to their contact and ingestion toxicites, may be the reason for their higher efficacy. While both systemic and contact properties might make the monocrotophos as the effective one. The good response of quinalphos may be due to its knock down effect in addition to contact, stomach activities. Less efficiency of thiodicarb and carbaryl may be due to their type of formulation i.e. as they are dusts, their adherence to the particles or rice bran will be relatively un-uniform when compared to the liquid formulations. The observations in the present study are in accordance with the reports of earlier workers in different moctuids. Rataul and Misra (1979) and Tiwari (1983) reported that spraying potato foilage and drenching the ridges with chlorpyriphos (Dursban) was effective against cut worms. Vijii and Bhagat (2001) stated that in maize plots where

TABLE 1. Efficacy of commonly used insecticides at different doses as baits to RHC

Sl. No.	Insecticide	Year 2000		Year 2001	
		a.i/ha (g)	Larval morality (%)	a.i/ha (g)	Larval morality (%)
1.	Chlorpyriphos	500	97.22[a]	200	88.85[a]
2.	Chlorpyriphos	250	88.85[cd]	100	83.16[b]
3.	Monocrotophos	900	92.90[b]	—	—
4.	Monocrotophos	450	86.94[d]	—	—
5.	Quinalphos	625	87.23[d]	250	83.01[b]
6.	Quinalphos	312.5	84.18[d]	125	69.72[c]
7.	Methomyl	660	91.59[bc]	—	—
8.	Methomyl	300	77.44[e]	—	—
9.	Thiodicarb	—	—	175	72.11[c]
10.	Thiodicarb	—	—	87.5	61.79[d]
11.	Carbaryl	—	—	500	64.17[d]
12.	Carbaryl	—	—	250	57.38[e]
13.	Untreated Control		0.00[f]		0.00[f]
		S.Em+	3.50		3.93
		C.D (0.05)	8.64		9.79

The figures indicated by the same alphabet are not statistically significant at 5% level by DMR.

seed was treated with chlorpyriphose Dursban), less infestation by the black cutworm, *Agrotis ipsilon* and high yield were recorded. Nair (1986) reported that the powerful contact insecticides may be used for the control of RHC. Abrol and Bhat (1996) reported that quinalphos and monocrotophos proved very effective against when tested along with cypermethrin and phosphmodon. Khurana (1996) stated *Helicoverpa* in tomato that carbaryl 50 WP when applied along with other dusts *viz.*, fenvalerate 0.4%, BHC 10%, methyl parathion 2%, endosulfan 4%, proved not effective against Helicoverpa in chickpea.

From the present findings it can be concluded that chlorpyriphos or quinalphos and monocrotophos can be recommended as baits to grownup RHC @ 250–450 g a.i./ha to reduce the larval numbers to more than 80 per cent.

REFERENCES

Abrol, D.P. and Bhat, A.A. (1996) Effect of spacing, intercropping and insecticides onthe management of tomato fruit borer, *Helociverpaarmigera*. *J. of Insect Sci.* **9**: 170–171.

Anonymous, (1997) Pesticide statistics. *Pesticide Res. Journal* **9(1)**: 12–13.

Khurna, A.D. (1996) Efficacy of some insecticidal dusts against gram podborer *Helociverpa armigera* on chickpea. *J. of Insect Sci.* **9**: 191–192.

Nair, M.R.G.K (1986) *In 'Insects and mites of crops in India'*. M.R.G.K., and Nair, (Eds). publised by I C A R: p 90.

Rataul, H.S. and Misra, S.S. (1979) Potato pests and their control. *Pesticides* **13(7)**: 27–38.
Tiwari, R.S. (1983) Salient points about potato production. *Indian farmers digest* **16(9)**: 28–30.
Vijii, C.P. and Bhagat, R.M. (2001) Bio-efficacy of some plant products, syntheticinsecticides and entamopathogenic fungi against black cut work.*Agrotis ipsilon* larvae of maize. *Indain J. of Ent.* **63**: 26–32.

(Received 9 April 2003; accepted 10 August 2003)

Entomon – Back volumes

All back volumes of **ENTOMON** from vol. No. 1, 1976 are available for sale. Please contact the Managing Editor for price and other details.

National Symposium on Aphids

A National Symposium on **Aphids in Agriculture and Forestry** will be held in the Department of Zoology, University of Kalyani, West Bengal, in collaboration with the Aphidological Society of India on 24–25 November 2004.

Contact person: Prof. Samiran Chakrabarti,
Department of Zoology, Kalyani University,
Kalyani 741235, West Bengal.
E-mail: chakrabarti32b@vsnl.net

INFORMATION TO CONTRIBUTORS

Scope: ENTOMON will accept original articles (but not reviews) arising from studies on insects, arachnids and myriapods. Papers dealing only with insecticide residue analysis and breeding plants for insect resistance, however, will not be considered. Papers on morphology, anatomy and histology (based on light microscopy, SEM or TEM) are acceptable only if they are related to physiology, behaviour or taxonomy.

General: Manuscripts submitted for publication in ENTOMON should not have been published or submitted for publication elsewhere. Three copies of the manuscript complete in all respects including figures (drawings or photographs) should be sent by registered post to the *Managing Editor,* ENTOMON, *Department of Zoology, University of Kerala, Kariavattom, Trivandrum 695581.* An electronic version of the paper need be sent only after acceptance of the paper for publication. If the paper has more than one author, the corresponding author should be indicated by an asterisk and footnote. At least one of the authors should be a member of the Association for Advancement of Entomology.

Articles should be in English. Normally, full papers should not exceed 6000 words and short communications, 1300 words. Announcements of Seminars/Symposia, book reviews and other items of entomological interest will also be considered for publication. Books for review may be sent to the Managing Editor.

Manuscript Preparation: Authors should consult a recent issue of the journal and carefully follow the style. Manuscripts should be typed double space, including Abstract, References and Legend, on one side of A4 size Bond paper, with 3.5 cm left margin and 2.5 cm right margin. Authors are advised to retain a copy of the manuscript since the journal cannot accept responsibility for damage or loss of papers.

Text: Normally, the paper should be organized into Introduction, Materials and Methods, Results, Discussion, Acknowledgements, and References. Short Communications should be organized in the same way, but without the sub-headings. Tables as well as figures (graphs, drawings, photographs) should be on separate sheets and appended at the end of the text.

Title page should contain the title, author name(s), affiliation, abstract, keywords, a short running title and footnote, if any.

Abstract should be informative, not indicative. It should highlight the major findings of the study in not more than 150 words, without any references.

Keywords should be limited to four or five; they will be used for compiling the index.

Introduction should contain a brief survey of the relevant literature and explain the reason for undertaking the work.

Materials and Methods should provide sufficient details of the materials as well as methods used for the study, to permit proper interpretation of the results. Technical description of the method is needed only where the method is new; if the method followed has been already described elsewhere, reference may be made to the earlier description.

Results should be presented in a clear, concise and summarised form. Where necessary, suitable statistical methods must be employed to analyse and interpret the data. The same data should not be presented in tables and figures.

Discussion should be separate from the results and should highlight the importance of the results in relation to published literature. A critical evaluation and interpretation of the findings, including discussion of the limitations of the study, is expected.

References should list all publications cited in the text, in alphabetical order. A previous issue of ENTOMON may be referred for citation style, except for the following: (i) Use a full stop after the paper title instead of comma, and (ii) Give the name of the journal in full instead of in abbreviated form.

Illustrations (line drawings, graphs, photographs) should be of high quality. They should be numbered consecutively as Fig. 1, Fig. 2, etc., without distinction between drawings and photographs. Labelling should be legible and large enough to stand suitable reduction (Refer previous issues of ENTOMON for guidance). Legend for the figures should be typed on separate sheets and not on the figures themselves. Reference to the illustrations must invariably be made in the text, at relevant places. The cost for reproduction of colour illustration is to be met by the author(s).

Electronic version: Supply of an electronic version of the final text (after acceptance of the paper and revision, if necessary) in a 3.5inch diskette in Unix or Windows format is desirable. Use of popular DTP software is not acceptable. ENTOMON is typeset in TEX. If you use TEX, prepare the manuscript using LATEX article macros. The diskette should carry a label showing author, title and filenames.

Page charges: With effect from **Volume 27**, page charges are applicable at the rate of Rs. 100.00 per printed page for authors in India and US$ 10.00 for authors overseas. Invoice will be sent to the author along with galley proof.

Reprints: Twentyfive reprints of the paper will be supplied free of cost to the author(s).

AUTHOR INDEX

Ananthakrishnan, T. N. , 1
Arunachalam, N. , 63

Das, S. Sam Manohar , 5

Gujar, G. T. , 75
Gupta, A. , 25
Gupta, S. , 25

Hiriyan, J. , 63

Ignacimuthu, S. , 81

James, Barish E., 13
Jauhari, R. K. , 31
Jayakumar, M. , 81
Jinham, A. Premjith , 5
Jobiraj, T. , 39

Kalaichelvan, T. , 89
Kalia, V. , 75
Kalia, Shamila , 85
Kamala Jayanthi, P. D. , 45
Kaur, J. , 69
Kirti, J. S., 69
Kumari, Archana , 75

Lingegowda, N. L. , 57

Manjula, K. , 97
Mathew, M. J., 51
Mohamed Jalaluddin, S. , 67

Narendran, T. C., 39
Natarajan, K. , 67

Omkar, , 12

Pandey, V. P. , 85
Pemola Devi, N. , 31
Philip Samuel, P. , 63
Prabu Seenivasan, S. , 81

Raja, N. , 81
Ramesh, S. R. , 57

Sebastian, P. A., 51
Sharma, B. N. , 89
Sudhikumar, A. V., 51

Thenmozhi, V. , 63

Usha Nandhini Devi, H. , 67

Verghese, Abraham , 45
Verma, K. K. , 89

Statement of ownership and other particulars about ENTOMON

(Form IV, Rule 8 of Registration of Newspapers (Central) Rules 1956)

1. Place of publication:	Trivandrum
2. Periodicity of publication:	Quarterly
3. Printer's name, nationality: and address:	D. Muraleedharan, Indian Department of Zoology, University of Kerala Kariavattom, Trivandrum 695581
4. Publisher's name, nationality and address:	-do-
5. Editor's name, nationality and address:	-do-
6. Name and address of the individual who owns the newspaper:	Association for Advancement of Entomology Department of Zoology, University of Kerala Kariavattom, Trivandrum 695581

I, D. Muraleedharan, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Sd/-
D. Muraleedharan
Publisher, ENTOMON

Trivandrum
31 March 2004

Reg. No. 123SBN

Susceptibility of the American Bollworm, *Helicoverpa armigera* (Hübner) from cotton ecosystem to *Bacillus thuringiensis* Berliner var. *kurstaki* HD-1: G. T. Gujar, Archana Kumari, V. Kalia. 75
Effect of bitter apple, *Citrullus colocynthis* (L.) Schrad seed extracts against pulse beetle, *Callosobruchus maculatus* Fab. (Coleoptera: Bruchidae): S. Prabu Seenivasan, M. Jayakumar, N. Raja, S. Ignacimuthu. 81
Biology of *Euproctis scintillans* Walk. (Lepidoptera: Lymantriidae) on its new host *Robinia pseudoacacia* L. from Himachal Pradesh: Shamila Kalia, V. P. Pandey. 85
Food plants of some Indian Cassidines (Coleoptera: Chrysomelidae): T. Kalaichelvan, K. K. Verma, B. N. Sharma. 89
Efficacy of different insecticides as baits against grown up larvae of the red hairy caterpillar, *Amsacta albistriga* (Lepidoptera: Arctiidae): K. Manjula. 97

Edited, printed and published by D. Muraleedharan for and on behalf of Association for Advancement of Entomology, Department of Zoology, University of Kerala, Trivandrum. Typeset in TEX by River Valley Technologies, Trivandrum. Printed at St. Joseph's Press, Trivandrum